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THE EFFECT OF INSTALLATION LOCATION ON RAILROAD HORN SOUND LEVELS

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1.0 Introduction

Many comments have been received as a result of the Federal Railroad Administration's (FRA) issuance of a Proposed Rule for the "Use of Locomotive Horns at Highway-Rail Grade Crossings"[1]. This rule contains numerous provisions, two of which are addressed in this study.

The first provision addressed in this study states that the sound level generated by the horn, when measured at the side of the locomotive, shall not exceed the sound level measured in front of the locomotive. In the late 1980's it became the de facto standard to install horns on the top/center portion of the locomotive. This was done in an attempt to reduce the noise exposure for the locomotive cab occupants. However, due to propagation effects at the measurement locations, the result was that measured sound levels off to the side of the locomotive were often higher than levels in front of the locomotive. The FRA proposed this provision to prevent the excessive distribution of sound to the side, which adds to community noise exposure. This provision could force railroad operators to relocate most center-installed horns. A large number of negative comments were received on this provision, suggesting that this relocation would be unacceptable for the locomotive crew.

The second provision states maximum sound levels could be established for the locomotive horn as follows: a 'low' maximum level of 104 dB(A), for use at active crossings; and a 'high' maximum level of 111 dB(A), for use at passive crossings. This was proposed in response to public concerns of unacceptable community noise exposure.

To respond to these comments and concerns the FRA, in conjunction with the Volpe National Transportation Systems Center, Environmental Measurement and Modeling Division, has undertaken a measurement study with the objective of documenting precisely the effect of installation location on the sound level output, directivity, and in-cab sound levels of railroad horns. This study documents and examines through measurements, the sound level inside and around the locomotive for five types of horns, installed in four locations on two models of locomotive. By measuring and documenting the sound level around multiple horn and locomotive combinations in a consistent manner, the change in directivity and cab noise levels, caused by a change of horn type, installation location or locomotive model can be evaluated.

2.0 Measurements

Measurements were conducted at the Transportation Test Center Inc. (TTCI), in Pueblo, CO, during the period April 10-12, 2001. The Test Center was selected for its remote location, which makes it ideal for acoustic testing. In addition, TTCI had available two types of locomotives and all necessary support equipment and personnel. Appendix A lists the members of the research team and their responsibilities.

2.1 Horns, Locomotives, and Installation Locations

The following five horns, provided by the manufacturers, were utilized for measurements. These horns represent the majority of horns that are currently in use.

1.) Airchime K-5-LA: A five-chime horn, operating at frequencies of 311, 370, 415, 494, and 622 Hz. The horn is rated by the manufacturer to have a sound level output of 114 dB(A) at 100 ft with a 90 psi air supply.

Figure 1. Airchime K-5-LA

2.) Airchime K-5-LAR24: Same as the above horn with 3 chimes facing forward and 2 chimes (370 and 494 Hz) facing rearward.

Figure 2. Airchime K-5-LAR24

3.) Leslie RS-3L: A three-chime horn, operating at frequencies of 255, 311, and 440 Hz. The horn is rated by the manufacturer to have a sound level output of 114 dB(A) at 100 ft with a 100 psi air supply.

Figure 3. Leslie RS-3L

4.) Leslie RS-3L-RF: Same as the above horn with one chime (440 Hz) facing rearward.

Figure 4. Leslie RS-3L-RF

Figure 5. Airchime P-3

5.) Airchime P-3: A three-chime horn, operating at frequencies of 277, 330, and 440 Hz. The horn is rated by the manufacturer to have a sound level output of 114 dB(A) at 100 ft with a 90 psi air supply.

The two locomotives used were chosen as representative of both older (1970's) and newer (1990's) technologies. They are depicted in Figures 6 and 7 and described as follows: (1.) an older General Motors EMD GP-40-2, Serial #786143-1. Overall dimensions: 15.2 feet in height, 10.2 feet in width, 59.2 feet in length. (2.) a newer General Motors EMD SD60MAC, BNSF #9501. Overall dimensions: 15.9 feet in height, 10.5 feet in width, 71.6 feet in length**.**

Figure 6. General Motors EMD GP-40-2

Figure 7. General Motors EMD SD60MAC

Four installation locations, described below and depicted in Figure 8, were chosen as representative of those currently in service. Note that all horns were centered over the width of the locomotive.

Figure 8. Horn Installation Locations

(1.) Center Installation
   a. GP-40. Installed on the top of the locomotive, 16 feet above ground level, 30 feet from the front of the locomotive.
   b. SD60MAC. Installed on the top of the locomotive, 16 feet above ground level, 40 feet from the front of the locomotive.

(2.) Cab Roof Installation
   a. GP-40. Installed on the top of the cab roof, 16 feet above ground level, 10 feet from the front of the locomotive.
   b. SD60MAC. Installed on the top of the cab roof, 16 feet above ground level, 7 feet from the front of the locomotive.

(3.) Front Hood Installation

a. GP-40. Installed on the top of the front hood, 12 feet above ground level, 5 feet from the front of the locomotive.
b. SD60MAC. Installed on the top of the front hood, 12 feet above ground level, 3 feet from the front of the locomotive.

(4.) Knuckle (Coupler) Installation

a. GP-40. Installed above the coupler, 3 feet above ground level, 0 feet from the front of the locomotive.
b. SD60MAC. Installed above the coupler, 3 feet above ground level, 0 feet from the front of the locomotive.

To facilitate installation changes, each horn was mounted on the locomotive using a magnetic base, and connected to the main air reservoir (pressurized to between 130 and 140 psi) via the main reservoir hose located on the front of the locomotive, next to the coupler. A control valve and pressure gauge were placed in the air line to monitor and regulate the air pressure delivered to the horn. Figure 9 shows this setup.

Figure 9. Air Pressure Control Valve/Pressure Gauge

2.2 Sound Measurement Locations

Sound level measurement instrumentation was positioned inside and around the locomotive in locations that would satisfy three types of measurement requirements: (1.) sound level as a function of location around the locomotive (directivity), at a constant distance from the horn, (2.) sound level per FRA certification regulations, at a constant distance from the front of the locomotive, and (3.) sound level inside the locomotive cab. Figure 10 is a plan view showing the measurement locations.

For directivity measurements, fourteen microphones were positioned as follows: four microphones, located 200 and 400 ft from the front of the horn and 200 and 400 ft to the side of the horn (90 degrees relative to the front of the horn), were connected to Larson-Davis Model 824 sound level meter / analyzers which were set up to measure and record both the overall A-weighted sound level and the sound level in one-third octave bands from 25 Hz to 10 kHz, at one-second intervals. The remaining ten microphones were positioned in a circular array at 45-degree increments, 100 and 200 feet from the horn,

and connected to Larson-Davis Model 820 sound level meters which were set up to measure and record the overall A-weighted sound level at one-second intervals. All distances were measured from the horn, allowing direct comparisons to be made between horn / locomotive / installation location configurations.

For FRA certification-type measurements, two microphones were positioned at a distances of 100 and 200 ft from the front of the locomotive, and connected to Larson-Davis Model 820 sound level meters, which were set up to measure and record the overall A-weighted sound level at one-second intervals.

To measure sound levels in the locomotive cab, a microphone was connected to a Larson-Davis Model 820 sound level meter, which was set up to measure and record the overall A-weighted sound level at one-second intervals. The microphone was placed inside the locomotive cab, ear-level at the engineer's typical position. Locomotive cab interior sound levels were measured both with the windows open (on both sides of the cab) and closed.

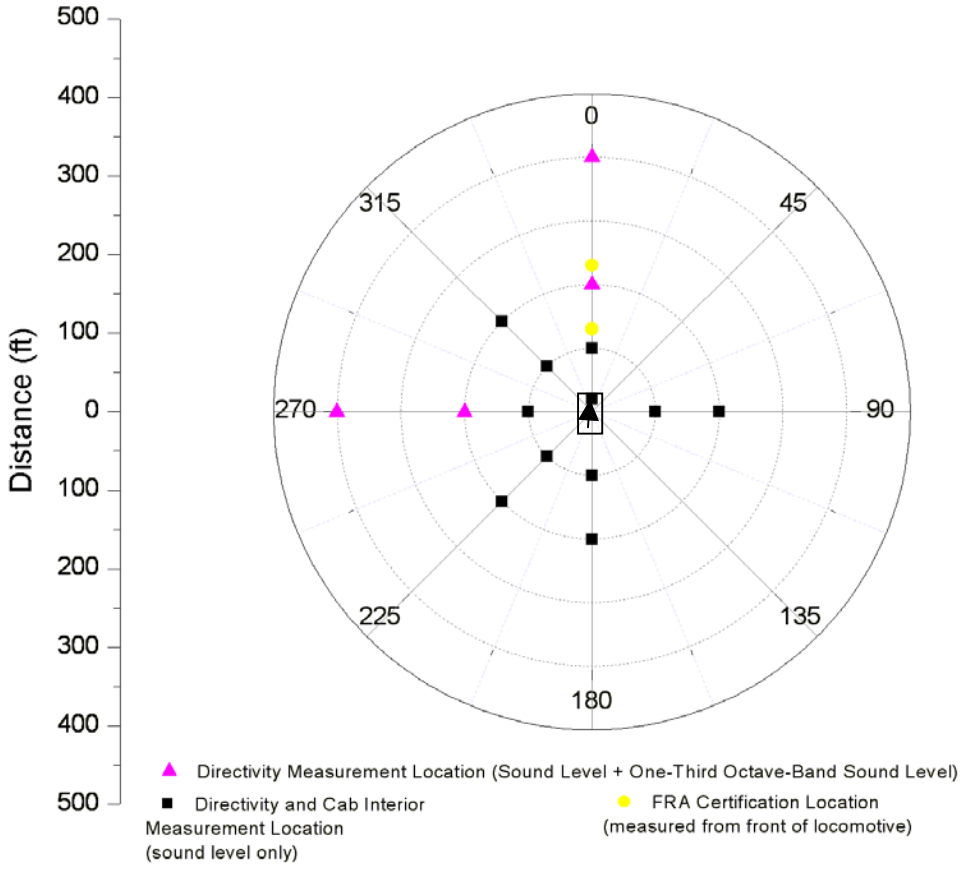

Figure 10. Plan View of Measurement Locations

2.3 Test Matrix

Sound levels were measured for each horn/locomotive/installation location combination at three different sound level/air pressure criterion. The first criterion was such that the horn was set to a constant air pressure (*constant pressure tests*). This allowed for accurate documentation of the barrier effect or shadow zone created by installing the horn in the center position on top of the locomotive. In this case, the air pressure delivered to the horn was 135 psi. This is the maximum pressure that could be consistently maintained in the main air reservoir.

The second and third criterion were such that the sound level output of the horn was adjusted (by adjusting the air pressure delivered to the horn) so that it achieved a specified level of (1.) 96 dB(A) and (2.) 111 dB(A) at the FRA certification position 100 ft in front of the locomotive (*constant level tests)*.

Tables 1 and 2 summarize the test matrix for the GP-40 and SD60MAC, respectively.

Table 1. Test Matrix, GP-40 Locomotive

Horn	Test Number	Installation Location	Test Criterion	Air Pressure delivered to horn (psi)
K-5-LA	**1B**	**Center**	**96 dB(A)**	50
	7B	**Cab Roof**		12*
	10C	**Front Hood**		10*
	11C	**Knuckle**		10*
K-5-LA		**Center**	**111 dB(A)**	**
	7A	**Cab Roof**		90
	10B	**Front Hood**		95
	11B	**Knuckle**		90
K-5-LA	**1A**	**Center**	**135 psi**	135
	6A	**Cab Roof**		135
	10A	**Front Hood**		135
	11A	**Knuckle**		135
K-5-LAR24	**4B**	**Center**	**96 dB(A)**	65
K-5-LAR24	**4A**	**Center**	**135 psi**	135
RS-3L	**3B**	**Center**	**96 dB(A)**	50
	8B	**Cab Roof**		24
	9C	**Front Hood**		20
	12C	**Knuckle**		20
RS-3L		**Center**	**111 dB(A)**	***
	8A	**Cab Roof**		135
	9B	**Front Hood**		85
	12B	**Knuckle**		66
RS-3L	**3A**	**Center**	**135 psi**	135
	8A	**Cab Roof**		135
	9A	**Front Hood**		135
	12A	**Knuckle**		135
RS-3L-RF	**2B**	**Center**	**96 dB(A)**	50
RS-3L-RF	**2A**	**Center**	**135 psi**	135

*This is below the pressure required for some of the horns (chimes) to sound.
**Not possible to measure data for test criterion of 111 dB(A), maximum achievable sound level at the certification location is 102 dB(A)
***Not possible to measure data for test criterion of 111 dB(A), maximum achievable sound level at the certification location is 101 dB(A)

Table 2. Test Matrix, SD60MAC Locomotive

Horn	Test Number	Installation Location	Test Criterion	Air Pressure delivered to horn (psi)
K-5-LA		**Center**	**96 dB(A)**	*
	15C	**Cab Roof**		46
	14C	**Front Hood**		32
	13C	**Knuckle**		32
K-5-LA		**Center**	**111 dB(A)**	*
	15B	**Cab Roof**		100
	14B	**Front Hood**		88
	13B	**Knuckle**		105
K-5-LA	**16A**	**Center**	**135 psi**	135
	15A	**Cab Roof**		135
	14A	**Front Hood**		135
	13A	**Knuckle**		135
P-3	**19A**	**Cab Roof**	**135 psi**	135
	18A	**Knuckle**		135

* Not possible to measure data for test criterion of 96 dB(A) or 111 dB(A), maximum achievable level at the certification location is 92 dB(A)

2.4 Measurement Procedure

Each acoustic measurement system was calibrated and the time-base was synchronized to a master clock at the beginning of each test day. Acoustic data were then measured simultaneously at the 17 positions for the duration of the test day.

A total of six uncontaminated events were measured for each of the specified test criteria in Tables 1 and 2. An event was defined as a 30-second period during which the horn was sounded continuously. To ensure the event was acoustically uncontaminated, wind speed and direction were measured continuously; if the wind speed exceeded 10 mph at any time during the event, the event was discarded. Baseline ambient noise levels at the test site, dominated by the idling locomotive, were always less than 65 dB(A). Since horn sound levels exceeded 75 dB(A) even at the farthest measurement locations, acoustic contamination from other noise sources was not a concern.

Because the measurement setup consisted of measurement systems that were 1). a constant distance from the horn (for directivity measurements) and 2.) a constant distance from the front of the locomotive (for certification measurements), a repositioning of some of the measurement systems was necessary when the horn installation location was changed. In order to expedite testing and keep the majority of the measurement systems at a fixed location for the duration of the study, it was decided that the locomotive and the

certification measurement systems should be repositioned when necessitated by a change in horn installation location. In other words, when the installation location was changed from the center to the cab-roof on the GP-40, the horn was kept in a fixed location, the locomotive was repositioned 23 feet to the rear, and the certification measurement systems were repositioned accordingly.

3.0 Acoustic Data Reduction

The contiguous, 1-second, A-weighted sound level data measured at each location were examined to determine the start and stop time for each event, as defined by the 10 dB-down period. The Maximum A-weighted Sound Level with slow time-weighting (L_{Asmx}) and Equivalent A-weighted sound level (L_{Aeq}) metrics for each event were calculated and transferred to a spreadsheet. The six events comprising each of the specified test criterion in Tables 1 and 2 were arithmetically averaged in the spreadsheet to determine a representative L_{Asmx} and L_{Aeq} for each criterion.

For comparative purposes, and to eliminate slight variations in sound level, measurements at all positions for the *constant level* criterion were normalized to the criterion level at the 100 ft certification microphone (i.e., if the average sound level at the 100 ft certification microphone for the 96 dB(A) criterion was 95.5 dB(A), 0.5 dB(A) was added to the levels at all 17 microphones in the array). This normalization process resulted in no more than a 2.1 dB(A) adjustment, with the majority of adjustments (84%), less than 1.0 dB(A).

If the 96 dB(A) or 111 dB(A) constant level criterion could not be met (i.e., the maximum achievable level at 100 ft forward of the locomotive was less than the criterion level), the constant pressure test data (i.e., the data that were representative of the maximum achievable levels) were normalized to the criterion level so that comparisons could be performed. For example, it was not possible to measure data for the 111 dB(A) test criterion for a K-5-LA installed in the center location on a GP-40 locomotive. The maximum sound level measured (using the maximum air pressure of 135 psi) at the position 100 ft forward of the locomotive was 101.4 dB(A). Therefore, 9.6 dB(A) were added to the aforementioned data, resulting in data that are representative of the 111 dB(A) criterion. Data that were derived through extrapolation are flagged and identified as such in subsequent sections. Table 3 summarizes the sources of each set of data and shows the magnitude of the extrapolation, where appropriate.

Table 3. Summary of Data Sources

		Installation	Test Critera		
Horn	Engine	Location	96 dB(A)	111 dB(A)	135 psi
K-5	GP-40	Center	Test 1B	Test 1A + 9.6 dBA	Test 1A
K-5	GP-40	Cab Roof	Test 7B	Test 7A	Test 6A
K-5	GP-40	Front Hood	Test 10C	Test 10B	Test 10A
K-5	GP-40	Knuckle	Test 11C	Test 11B	Test 11A
RS-3L	GP-40	Center	Test 3B	Test 3A + 11.1 dBA	Test 3A
RS-3L	GP-40	Cab Roof	Test 8B	Test 8A	Test 8A
RS-3L	GP-40	Front Hood	Test 9C	Test 9B	Test 9A
RS-3L	GP-40	Knuckle	Test 12C	Test 12B	Test 12A
K-5-LAR24	GP-40	Center	Test 4B	Test 4A + 12.2 dBA	Test 4A
K-5-LAR24	GP-40	Cab Roof	Test 5A – 15 dBA	Test 5A	Test 5A
RS-3L-RF	GP-40	Center	Test 2B	Test 2A + 10.8 dBA	Test 2A
K-5	MAC-60	Center	Test 16A + 3.7 dBA	Test 16A + 18.7 dBA	Test 16A
K-5	MAC-60	Cab Roof	Test 15C	Test 15B	Test 15A
K-5	MAC-60	Front Hood	Test 14C	Test 14B	Test 14A
K-5	MAC-60	Knuckle	Test 13C	Test 13B	Test 13A
P-3	MAC-60	Cab Roof	Test 19A – 15 dBA	Test 19A	Test 19A
P-3	MAC-60	Knuckle	Test 18A – 15 dBA	Test 18A	Test 18A

Tables of the average L_{Aeq} at each microphone position for each test criterion can be found in Appendix B. Directivity contours, which are structured to allow comparisons between installation locations, can be found in Appendix C.

4.0 Data Analysis

In this section, the data collected were used to empirically derive a measure of the horn installation effect and the excess ground attenuation. The horn installation effect is a term used to describe the sound level reduction, or 'shadow' around the locomotive as a result of diffraction during propagation over the locomotive body. Excess ground attenuation results from propagation over acoustically soft ground (as was the case in this study). The ground surface will generally absorb some of the sound, resulting in lower sound levels at a distance from the source. The lower the height of the sound source, the greater the attenuation.

Because a horn operating at a fixed pressure will, theoretically, always produce the same sound level output at a given measurement location, the sound level data measured at a constant distance from the horn for the *constant pressure* test criterion should be identical for all horn/locomotive installations. Any relative differences in these data are caused by the horn installation effect and/or excess ground attenuation. Sections 4.1 and 4.2, respectively, describe how these data were used to empirically derive the horn installation effect and the excess ground attenuation.

4.1 Horn Installation Effect (A_{INST})

As stated earlier, the horn installation effect is a term used to describe the sound level reduction, or 'shadow' around the locomotive as a result of diffraction during propagation over the locomotive body. The diffracted sound wave is reduced in magnitude (i.e., loudness), based on the frequency composition of the sound and the angles and distances from the diffraction point (i.e., the front edge of the roof of the locomotive) to the horn and receiver. The installation effect is most pronounced when the receiver is close to the locomotive and at low height (relative to the height of the locomotive). The installation effect diminishes as the receiver moves farther away from the front of the locomotive and/or higher above ground level, diminishing to zero when a visual line-of-sight to the horn is achieved.

When the locomotive horn is installed in the center position, the installation effect causes concern because the effect is very pronounced at the compliance measurement location specified by FRA regulations, 49 CFR Part 229.129[2]. This regulation specifies a measurement position 100 ft from the front knuckle, 4 ft above ground level (AGL), directly in front of the locomotive.

In order to assess the magnitude of this concern, the installation effect in front of the locomotive for the center-installed horn was determined by comparing the sound level data measured directly in front of the locomotive (4 ft. AGL, 100, 200, and 400 ft from the horn) for the center-installation with data measured at the identical distances from the horn for the cab-roof installation. Because the cab-roof installed horn is at the same height as the center installed, it was assumed that there was no difference in the excess ground attenuation (see Section 4.2), and any differences between these installations

could be attributed to the installation effect. A similar comparison was performed for the measurement locations at other directivity angles.

Figure 11 graphically depicts the installation effect (center-installed sound level minus cab-roof installed sound level), at distances of 100, 200, and 400 feet from the horn, plotted as a function angular directivity for the Airchime K-5-LA installed at these two locations on the GP-40 locomotive. It can be seen that the installation effect (or "shadow") caused by diffraction over the locomotive body results in a 10 dB reduction in sound level at the '0 degree' position, 100 feet from the horn, decreasing to 9 dB, 200 ft from the horn, and 8.1 dB, 400 feet from the horn. The majority of the measurement locations at other directivity angles show only a slight increase in sound level (i.e., the center installed horn produces slightly higher levels than the cab-roof installed horn), indicating that the sound level output of the center-installed horn is nearly identical to the sound-level output of the cab-roof installed horn toward the sides and rear of the locomotive.

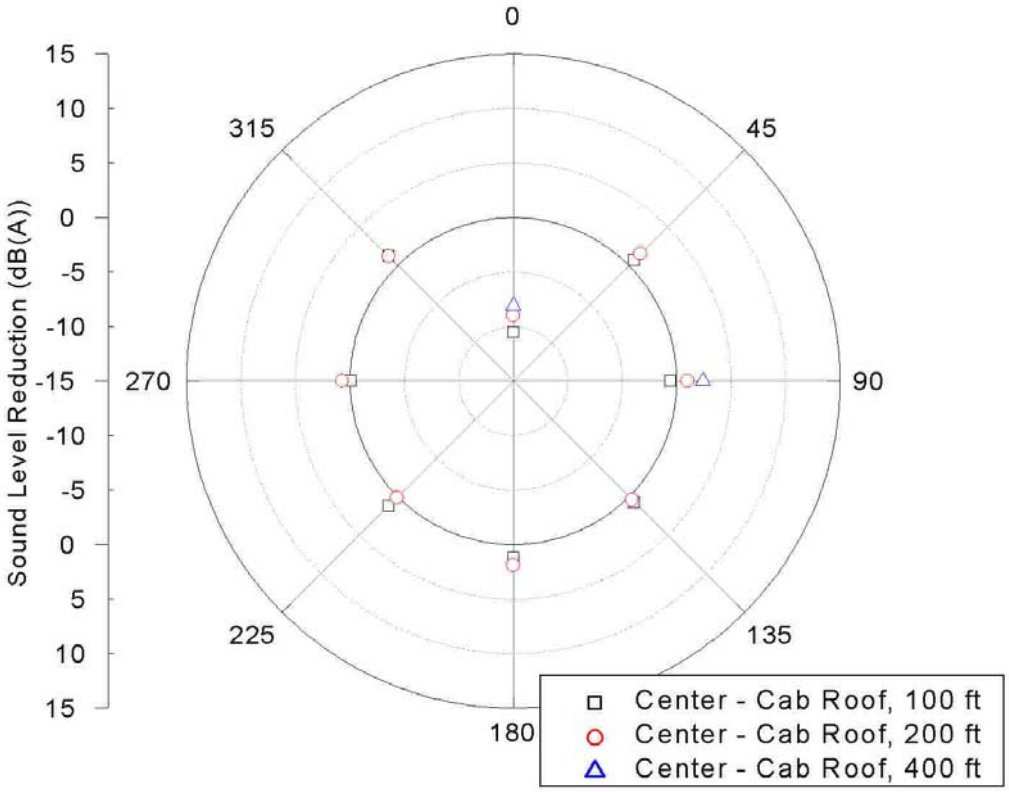

Figure 11. Center-Installed vs. Cab Roof Installed Sound Levels

Table 4 summarizes the magnitude of the installation effect for each horn / locomotive combination tested for the measurement positions directly in front of the locomotive.

Table 4. Summary of Installation Effect

			'0' degree Installation Effect (A_{INST}) dB(A)		
			Distance from Horn to Measurement Position (ft)		
Horn	Locomotive	Distance from Horn to Front of Locomotive (ft) for Center-Installed Horn	100	200	400
K-5-LA	GP-40	30	-10	-9	-8.1
K-5-LAR24	GP-40	30	-10.8	-9.1	-9.5
RS-3L	GP-40	30	-9.8	-7.9	-6.8
K-5-LA	MAC-60	40	-18.3	-15.7	-15.1

In general, it can be said that the magnitude of the installation effect (shadow) when measured at locations directly in front of the GP-40 locomotive, 4 feet above ground, averages 10.2 dB(A), 100 feet from the horn, 8.7 dB(A), 200 feet from the horn, and 8.1 dB(A) 400 feet from the horn. The magnitude of the installation effect when measured directly in front of the MAC-60 locomotive, as seen in Table 4, is 18.3 dB(A) at 100 feet, 15.7 dB(A) at 200 feet, and 15.1 dB(A) at 400 feet. Although it is less pronounced, the installation effect is still large enough to be of concern at forward measurement distances out to 400 feet.

Also worthy of note is the large variation in the horn installation effect caused by seemingly small differences in the center-mount location between engine models. This variation can be attributed to: (1) the distance from the horn to the front of the locomotive, (2) the horn height above ground, (3) the horn height above the roof, and (4) variations in the roof profile between engine models. This suggests that it is improper assume that the installation effect will be consistent from one situation to the next.

4.2 Excess Ground Attenuation (A_{GND})

The reduction in sound level over distance, caused by excess ground attenuation, geometric spreading, and atmospheric absorption, is usually reported in terms of a drop-off rate (X dB per distance doubling). Geometric spreading from a point source such as a stationary locomotive horn results in a 6 dB reduction for every doubling of distance. Atmospheric absorption can be effectively neglected for the small distances and low frequencies examined in the current study. Any variance measured in drop-off rate from 6 dB(A) can therefore be attributed to excess ground attenuation. The following Tables summarize the drop-off rate (dB / distance doubling) for each horn installation as a function of angle, for the measurement locations depicted in Figure 10.

Table 5. Drop off rate (L_{Aeq} at 200 ft minus L_{Aeq} at 100 ft) for Center-Installed Horns (16 feet above ground level)

		Angular Position					
Engine	**Horn**	**0 degrees**	**315 degrees**	**270 degrees**	**225 degrees**	**90 degrees**	**Average**
GP-40	**K-5-LA**	*	-4.7	-5.8	-4.6	-6.3	**-5.3**
GP-40	**RS-3L**	*	-4.2	-8.1	-5.1	-6.4	**-6.0**
GP-40	**K-5-LAR24**	*	-4.8	-6.9	-5.3	-7.4	**-6.1**
GP-40	**RS-3L-RF**	*	-4.7	-5.5	-5.1	-5.3	**-5.1**
MAC-60	**K-5-LA**	*	-4.5	-8.9	-4.7	-5.4	**-5.9**
	Average		**-4.6**	**-7.0**	**-4.9**	**-6.2**	**-5.7**

* Due to the influence of the locomotive body at this position, it was eliminated from analysis.

Table 6. Drop off rate (L_{Aeq} at 200 ft minus L_{Aeq} at 100 ft) for Cab Roof-Installed Horns (16 feet above ground level)

		Angular Position					
Engine	**Horn**	**0 degrees**	**315degrees**	**270degrees**	**225 degrees**	**90 degrees**	**Average**
GP-40	**K-5-LA**	-6.8	-5.0	-8.6	-4.7	-7.2	**-6.5**
GP-40	**RS-3L**	-6.3	-5.2	-9.2	-5.3	-7.5	**-6.7**
GP-40	**K-5-LAR24**	-6.2	-5.3	-7.8	-3.8	-6.9	**-6.0**
MAC-60	**K-5-LA**	-6.7	-6.1	-8.2	-4.3	-6.8	**-6.4**
MAC-60	**P-3**	-9.2	-3.8	-8.2	-2.3	-5.7	**-5.8**
	Average	**-7.1**	**-5.1**	**-8.4**	**-4.1**	**-6.8**	**-6.3**

Table 7. Drop off rate (L_{Aeq} at 200 ft minus L_{Aeq} at 100 ft) for Front Hood-Installed Horns (12 feet above ground level)

		Angular Position					
Engine	**Horn**	**0 degrees**	**315degrees**	**270degrees**	**225 degrees**	**90 degrees**	**Average**
GP-40	**K-5-LA**	-7.1	-7.6	-7.2	-5.7	-7.5	**-7.0**
GP-40	**RS-3L**	-6.6	-6.5	-7.5	-7.8	-8.7	**-7.4**
MAC-60	**K-5-LA**	-6.8	-7.2	-8.4	-5.3	-9.6	**-7.5**
	Average	**-6.8**	**-7.1**	**-7.7**	**-6.3**	**-8.6**	**-7.3**

Table 8. Drop off rate (LAeq at 200 ft minus LAeq at 100 ft) for Knuckle-Installed Horns (3 feet above ground level)

		Angular Position					
Engine	**Horn**	**0 degrees**	**315degrees**	**270degrees**	**225 degrees**	**90 degrees**	**Average**
GP-40	**K-5-LA**	-8.0	-9.2	-8.4	-7.2	-7.8	**-8.1**
GP-40	**RS-3L**	-8.4	-9.3	-8.3	-6.5	-7.1	**-7.9**
MAC-60	**K-5-LA**	-9.4	-9.0	-10.3	-9.2	-7.9	**-9.2**
MAC-60	**P-3**	-17.4*	-18.0*	-15.2*	-13.1*	-7.3*	**-14.2***
	Average	**-8.6**	**-9.2**	**-9.0**	**-7.6**	**-7.6**	**-8.4**

*It is unclear why the drop-off rate for this horn is much larger than the others. It was eliminated from analysis and not reflected in the presented averages.

It can be seen that, as expected, the drop-off rate increases with decreasing horn height, that is to say that the drop-off rate is higher for propagation paths closer to the acoustically soft ground. The average drop-off rates are 5.7 dB, 6.3 dB, 7.3 dB, and 8.4 dB for the horn placed at heights of 16 ft, 16 ft, 12 ft, and 3 ft, respectively. Because the cab-roof-installed and center-installed horns were at the same height, the results were averaged together. As a result, for the 16 ft height, the average drop-off is 6.0 dB; this signifies that there is no excess ground attenuation at 16 ft.

4.3 Directional vs. Bi-Directional Horns

Figure 12 shows a plot of the directivity of the directional Airchime K-5-LA (all five chimes are facing forward) in contrast to the directivity of the bi-directional Airchime K-5-LAR24 (3 chimes facing forward, 2 chimes facing rearward). These data are representative of sound levels measured at 100 ft for a cab-roof installation under constant pressure test conditions.

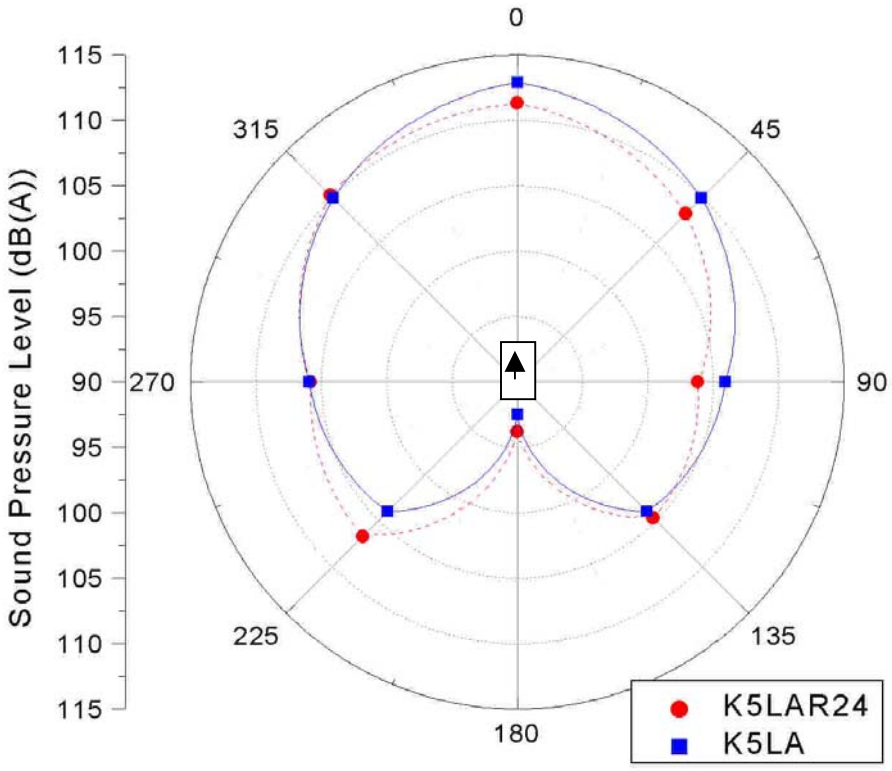

Figure 12. Directivity of Directional and Bi-Directional Horns

As expected, the bi-directional horn projects less sound pressure to the front of the locomotive and more sound pressure to the rear of the locomotive, as compared to the directional horn. Table 9 shows the relative differences in sound level output at the 100 ft measurement distance for the directional horns when compared to their bi-directional

equivalents. It shows that the aforementioned trend is also evident in other horn/installation location combinations. Note that the sound level differences measured at 90 degrees appear to vary with installation location.

Table 9. Sound Level Output Differences: Directional minus Bi-Directional Horns

Horns / Engine	Cab-Roof			Center		
	0 degrees	90 degrees	180 degrees	0 degrees	90 degrees	180 degrees
K-5-LA K-5-LAR24/ GP40	1.8	2.1	-1.3	2.6	-1	-1.4
RS-3L RS-3L-RF/ GP40				0.7	-0.2	-3.1

4.4 Locomotive Cab Interior Noise Levels

Tables 10 and 11 and Figure 13 summarize the sound levels measured in the locomotive cab interior. These sound levels are also detailed in Appendix B. In general, the following conclusions can be reached:

- There is a negligible difference in interior levels between the cab roof and front hood positions.
- Moving the horn from the cab-roof to the center of the locomotive or the front knuckle will provide a substantial reduction in interior levels, usually between 3 and 18 dB(A).
- Closed windows provide between 5 and 15 dB(A) of sound level reduction. This is consistent with previous research on the sound level reduction of locomotive cab windows[3] and automobile windows[4].
- Levels in the newer SD60MAC average 5.5 dB(A) lower than in the older GP-40.

Table 10. GP-40 Average Sound Levels, (L_{Aeq}) in the Locomotive Cab

Horn	Installation Location	Test Criterion	L_{Aeq}, Windows Open	L_{Aeq}, Windows Closed
K-5-LA	Center	96 dB(A)	96.5	82.2
	Cab Roof			82.9
	Front Hood		96.7	81.8
	Knuckle		92.1	79.2
K-5-LA	Center	111 dB(A)	110.2**	96.4**
	Cab Roof		105.1	96.5
	Front Hood		105.4	94.2
	Knuckle		98.0	90.6
K-5-LA	Center	135 psi	100.6	86.8
	Cab Roof		104.9	96.3
	Front Hood		108.7	98.8
	Knuckle		99.4	91.8
K-5-LAR24	Center	96 dB(A)	97.8	84.3

Horn	Installation Location	Test Criterion	L_{Aeq}, Windows Open	L_{Aeq}, Windows Closed
	Cab Roof		89.3**	83.0**
K-5-LAR24	Center	135 psi	101.4	86.0
	Cab Roof		104.0	97.7
RS-3L	Center	96 dB(A)	93.0	82.8
	Cab Roof		96.2	92.4
	Front Hood		95.7	91.4
	Knuckle		87.8	74.6
RS-3L	Center	111 dB(A)	109.1***	98.8***
	Cab Roof		105.3	98.1
	Front Hood		105.8	93.1
	Knuckle		95.2	83.8
RS-3L	Center	135 psi	98.0	87.7
	Cab Roof		106.1	98.9
	Front Hood			95.3
	Knuckle		96.6	86.4
RS-3L-RF	Center	96 dB(A)	94.6	83.4
RS-3L-RF	Center	135 psi	99.7	87.4

**Not possible to measure data for test criterion of 111 dB(A), maximum achievable sound level at the certification location is 102 dB(A)
***Not possible to measure data for test criterion of 111 dB(A), maximum achievable sound level at the certification location is 101 dB(A)

Table 11. SD60MAC Average Sound Levels, (L_{Aeq}) in the Locomotive Cab

Horn	Installation Location	Test Criterion	L_{Aeq}, Windows Open	L_{Aeq}, Windows Closed
K-5-LA	Center	96 dB(A)	98.4*	83.1*
	Cab Roof		90.2	81.4
	Front Hood		88.7	80.2
	Knuckle			
K-5-LA	Center	111 dB(A)	113.4*	98.1*
	Cab Roof		99.4	91.8
	Front Hood		104.9	90.7
	Knuckle		92.2	79.7
K-5-LA	Center	135 psi	94.7	79.4
	Cab Roof		99.4	92.5
	Front Hood		103.9	91.2
	Knuckle		93.2	80.7
P-3	Cab Roof	135 psi	94.5	89.1
	Knuckle		91.3	76.7

* Not possible to measure data for test criterion of 96 dB(A) or 111 dB(A), maximum achievable level at the certification location is 92 dB(A)

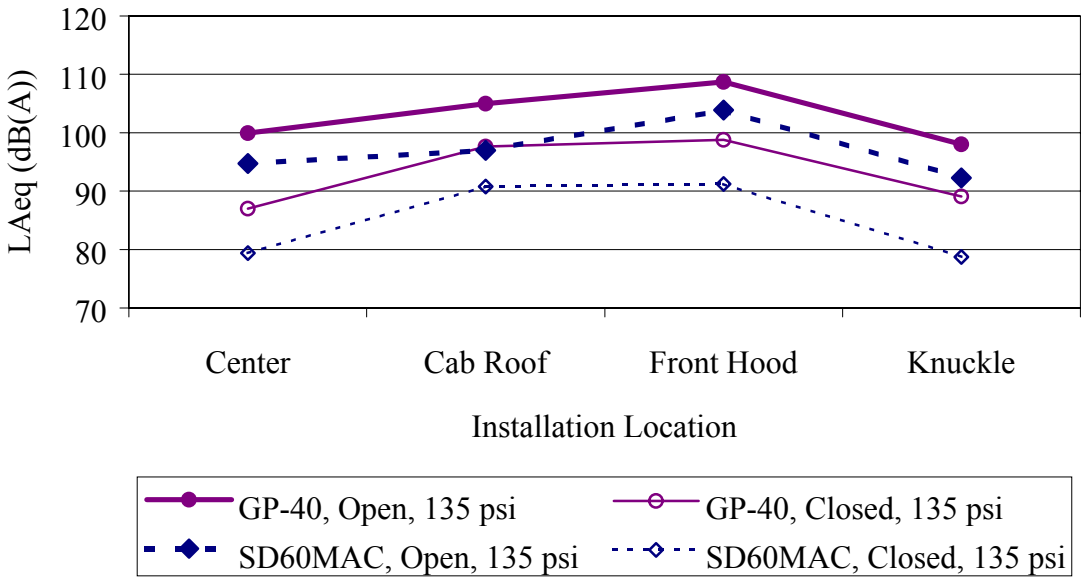

Figure 13. Locomotive Cab Interior Noise Levels

5.0 References

[1] . Federal Register, January 13, 2000. *Use of Locomotive Horns at Highway-Rail Grade Crossings; Proposed Rule*. U.S. Department of Transportation, Federal Railroad Administration.
[2] Federal Register, March 31, 1980. *Audible Warning Device*. U.S. Department of Transportation, Federal Railroad Administration.
[3] Kilmer, R.D., *Assessment of Locomotive Crew In-Cab Occupational Noise Exposure.* Report No. FRA/ORD-80/91, December, 1980.
[4] Potter, R.C., Fidell, S.A., Myles, M.M., and Keast, D.N. *Effectiveness of Audible Warning Devices on Emergency Vehicles*. Report No. DOT-TSC-OST-77-38, August, 1977.

Appendix A:
Study Team Members and Responsibilities

Federal Railroad Administration, Office of Passenger Programs:

David Valenstein, Environmental Program Manager
Mr. Valenstein was responsible for the senior management of all aspects of the study.

Federal Railroad Administration, Transportation Technology Center Inc.:

Gunars Spons, FRA Resident Engineering Manager
Mr. Spons served as the main point-of-contact at TTCI, and participated in pre-test planning.

Volpe National Transportation Systems Center, Environmental Measurement and Modeling Division:

Amanda S. Rapoza, Acoustics Engineer
Ms. Rapoza was in charge of all aspects of the study design, acoustic measurements, data reduction and data analysis.

Gregg G. Fleming, Chief, Environmental Measurement and Modeling Division
Mr. Fleming was responsible for the senior management of all aspects of the study.

Cynthia S.Y. Lee, Acoustics Engineer
Ms. Lee was in charge of all of the acoustics-related instrumentation, and was a member of the team that performed the acoustic measurements.

Clay Reherman, Acoustics Engineer
Mr. Reherman was a member of the team that performed the acoustic measurements, and participated in data reduction and analysis of excess ground attenuation.

David R. Read, Computer Specialist
Mr. Read was responsible for the development, configuration, and testing of the acoustics-related instrumentation.

Judith Rocaht, Acoustics Engineer
Dr. Rochat was responsible for the development of the enhancements to the spreadsheet program which calculates acoustic signal detectability.

Transportation Test Center, Inc.

Mr. Thomas Roderick, Test Controller
Mr. Roderick was responsible for all railroad-related aspects of the study, including locomotive positioning, air pressure regulation setup, and horn operation.

Mr. Mark White, Senior Engineer
Mr. White was responsible for test planning and oversight**.**

APPENDIX B
ACOUSTIC DATA SUMMARY

Table B-1
As-Measured Acoustic Data
Airchime K-5-LA, Center-Installed, GP-40 Locomotive
135 psi delivered to horn

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	103.1
2	200	0	98.0
3	400	0	91.3
4	100	45	110.6
5	200	45	106.0
6	100	90	105.3
7	200	90	99.1
8	400	90	93.6
9	100	135	104.7
10	200	135	100.2
11	100	180	93.7
12	200	180	90.8
13	100	270	106.0
14	200	270	99.8
1C	130	0	101.4
2C	230	0	96.8
15O	Cab, Windows Open		100.6
15C	Cab, Windows Closed		86.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.9	61.4	70.4	60.0	48.7	50.3	51.6	52.6	88.3	92.4	86.3	77.7
3	400	0	64.3	55.7	61.3	53.0	43.7	41.4	41.1	43.7	82.3	88.7	84.1	75.9
8	400	90	69.8	60.9	70.2	62.2	49.6	44.0	42.2	40.0	75.9	84.4	82.7	90.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
89.4	90.3	88.4	83.3	89.7	86.3	84.7	81.7	79.4	76.3	71.7	66.4
79.0	79.6	82.7	80.1	80.2	80.8	78.2	74.3	71.3	66.4	59.6	51.3
90.7	82.2	79.5	76.9	78.6	74.7	73.2	67.9	63.1	56.6	48.6	38.7

Table B -2
As-Measured Acoustic Data
Airchime K-5-LA, Center-Installed, GP-40 Locomotive
96 dB(A) 100 ft forward of the locomotive

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	97.4
2	200	0	92.2
3	400	0	85.7
4	100	45	105.1
5	200	45	100.4
6	100	90	100.4
7	200	90	94.0
8	400	90	88.7
9	100	135	100.8
10	200	135	96.1
11	100	180	89.8
12	200	180	86.6
13	100	270	101.4
14	200	270	95.0
1C	130	0	95.7
2C	230	0	91.3
15O	Cab, Windows Open		100.6
15C	Cab, Windows Closed		86.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.4	60.9	70.3	60.0	47.1	49.9	46.4	49.7	86.0	90.1	83.1	73.2
3	400	0	63.8	55.0	61.0	52.8	41.5	41.3	36.2	39.8	78.8	85.4	78.8	74.2
8	400	90	69.4	60.8	70.2	61.7	47.2	44.2	36.4	35.0	73.9	81.9	78.2	83.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
81.6	83.9	84.2	77.8	82.4	78.5	76.3	72.7	70.4	66.6	61.7	55.8
71.7	71.9	76.4	76.1	73.2	70.6	69.7	65.7	62.2	56.5	49.0	39.9
86.3	78.2	77.7	73.2	71.1	68.0	64.3	58.3	53.1	45.3	37.3	28.4

Table B -3
As-Measured Acoustic Data
Leslie RS-3L-RF, Center-Installed, GP-40 Locomotive
135 psi delivered to horn

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	101.9
2	200	0	97.3
3	400	0	91.0
4	100	45	106.7
5	200	45	102.3
6	100	90	103.3
7	200	90	98.6
8	400	90	93.3
9	100	135	102.8
10	200	135	98.5
11	100	180	94.0
12	200	180	90.3
13	100	270	103.7
14	200	270	99.0
1C	130	0	100.2
2C	230	0	95.8
15O	Cab, Windows Open		100.6
15C	Cab, Windows Closed		86.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.2	61.1	70.6	60.1	47.0	49.3	47.5	88.3	90.9	85.9	86.0	80.1
3	400	0	63.3	55.1	61.1	52.7	40.7	41.4	38.0	77.8	82.5	81.7	81.5	82.3
8	400	90	69.1	60.5	70.0	61.4	45.9	44.6	37.4	71.0	77.7	78.7	81.0	82.7

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
83.4	90.8	90.0	84.5	88.5	85.2	81.4	79.5	77.3	73.2	68.5	62.9
77.8	81.1	81.9	82.2	83.3	77.9	74.4	72.6	69.0	63.5	57.0	48.5
86.4	86.4	88.8	78.5	78.1	73.1	71.1	65.5	60.6	53.0	45.7	35.2

Table B -4
As-Measured Acoustic Data
Leslie RS-3L-RF, Center-Installed, GP-40 Locomotive
96 dB(A) 100 ft forward of the locomotive

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	97.8
2	200	0	93.6
3	400	0	88.3
4	100	45	103.2
5	200	45	98.3
6	100	90	101.0
7	200	90	95.2
8	400	90	89.2
9	100	135	100.7
10	200	135	94.9
11	100	180	89.8
12	200	180	87.0
13	100	270	100.4
14	200	270	94.6
1C	130	0	96.1
2C	230	0	92.7
15O	Cab, Windows Open		94.7
15C	Cab, Windows Closed		83.5

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.4	61.3	70.2	60.0	45.9	49.0	46.7	87.4	88.3	84.1	87.6	80.2
3	400	0	63.5	55.4	61.1	52.5	39.4	41.7	37.4	76.2	77.1	78.4	81.5	79.8
8	400	90	68.9	60.7	69.8	60.9	46.0	42.8	36.6	71.0	76.4	76.2	82.4	80.5

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
77.9	86.8	86.4	82.3	81.4	79.0	76.4	74.9	71.2	66.8	60.5	54.5
75.2	79.8	79.2	78.7	79.4	74.9	72.4	67.8	64.4	59.1	52.0	42.0
81.7	83.2	83.4	72.8	71.4	66.8	62.0	56.9	51.5	46.4	38.9	28.8

Table B -5
As-Measured Acoustic Data
Leslie RS-3L, Center-Installed, GP-40 Locomotive
135 psi delivered to horn

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	102.6
2	200	0	98.2
3	400	0	93.8
4	100	45	106.9
5	200	45	102.8
6	100	90	103.0
7	200	90	97.1
8	400	90	87.9
9	100	135	101.2
10	200	135	96.7
11	100	180	90.9
12	200	180	87.1
13	100	270	103.7
14	200	270	97.8
1C	130	0	100.9
2C	230	0	97.2
15O	Cab, Windows Open		98.0
15C	Cab, Windows Closed		87.7

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.1	61.2	70.5	60.3	47.2	49.1	47.4	88.5	90.3	88.0	88.4	85.8
3	400	0	63.2	55.5	61.9	53.0	41.6	42.3	39.0	77.2	78.5	79.2	80.3	83.4
8	400	90	68.8	60.2	69.2	60.5	45.9	45.4	42.6	74.0	79.1	80.4	80.9	79.7

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
82.4	89.2	91.2	88.9	88.5	85.8	84.0	79.7	76.7	72.3	67.0	61.1
80.1	84.4	85.4	84.7	86.4	83.1	79.9	75.9	71.6	64.9	58.3	49.9
78.2	79.8	78.4	78.0	77.0	74.5	67.0	65.1	59.6	51.7	43.9	33.2

Table B -6
As-Measured Acoustic Data
Leslie RS-3L, Center-Installed, GP-40 Locomotive
96 dB(A) at 100 ft

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	98.1
2	200	0	93.9
3	400	0	88.8
4	100	45	103.4
5	200	45	99.1
6	100	90	99.9
7	200	90	93.0
8	400	90	82.6
9	100	135	99.5
10	200	135	93.8
11	100	180	86.4
12	200	180	84.2
13	100	270	100.3
14	200	270	93.4
1C	130	0	96.4
2C	230	0	93.3
15O	Cab, Windows Open		93.4
15C	Cab, Windows Closed		83.2

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.1	61.5	70.3	60.3	46.5	48.6	46.7	87.8	87.4	83.7	88.6	84.3
3	400	0	63.0	55.8	62.0	53.0	40.4	41.8	38.3	76.5	76.9	75.3	80.5	80.2
8	400	90	68.7	60.1	69.3	60.1	46.1	43.3	40.2	73.1	76.4	75.2	80.9	75.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
80.3	85.8	85.6	83.2	82.2	78.8	79.0	74.1	70.4	65.5	59.9	53.7
76.6	81.0	80.0	78.7	79.7	76.4	74.5	70.4	65.3	58.6	51.4	42.0
72.9	74.5	70.7	66.2	65.8	62.6	58.3	53.5	47.8	41.5	32.9	23.6

Table B -7
As-Measured Acoustic Data
Airchime K-5-LAR24, Center-Installed, GP-40 Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	100.5
2	200	0	96.0
3	400	0	89.3
4	100	45	108.5
5	200	45	103.3
6	100	90	106.2
7	200	90	99.0
8	400	90	93.1
9	100	135	107.0
10	200	135	101.5
11	100	180	95.1
12	200	180	91.9
13	100	270	106.0
14	200	270	98.8
1C	130	0	98.8
2C	230	0	95.0
15O	Cab, Windows Open		101.4
15C	Cab, Windows Closed		86.0

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.2	61.9	70.4	60.5	47.6	48.9	50.3	52.1	88.5	93.9	89.9	80.3
3	400	0	63.2	57.2	62.3	53.4	41.2	41.9	40.5	41.2	77.1	84.7	81.1	73.9
8	400	90	69.2	60.9	69.8	61.1	49.2	45.0	45.2	42.8	77.5	82.5	84.6	88.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
83.1	86.2	85.2	84.8	84.6	84.9	82.7	77.7	73.8	69.8	63.9	57.3
79.3	80.3	78.5	78.7	80.0	78.5	76.3	71.7	67.1	61.5	54.2	44.5
87.6	84.5	81.8	83.2	78.8	77.0	74.3	68.5	64.6	57.1	48.9	39.0

Table B -8
As-Measured Acoustic Data
Airchime K-5-LAR24, Center-Installed, GP-40 Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	97.6
2	200	0	93.5
3	400	0	87.0
4	100	45	104.2
5	200	45	99.8
6	100	90	102.4
7	200	90	94.8
8	400	90	87.7
9	100	135	104.0
10	200	135	99.0
11	100	180	92.9
12	200	180	90.1
13	100	270	103.9
14	200	270	96.3
1C	130	0	95.9
2C	230	0	92.9
15O	Cab, Windows Open		97.7
15C	Cab, Windows Closed		84.2

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.3	61.7	70.2	60.1	46.7	48.9	47.2	49.2	86.9	91.7	87.0	83.1
3	400	0	63.3	57.1	62.1	52.8	41.1	42.4	39.5	39.4	75.8	83.4	77.4	76.4
8	400	90	69.0	60.5	69.5	60.8	48.0	44.9	41.2	39.3	76.2	80.3	80.0	82.0

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
83.0	81.7	82.4	84.1	82.0	79.8	78.4	73.7	68.2	62.6	56.6	49.6
76.7	76.6	77.0	77.2	77.7	76.2	72.6	67.5	62.6	56.0	48.4	38.0
82.5	77.7	75.9	78.9	72.4	69.4	68.4	61.2	56.7	48.7	40.6	31.1

Table B -9
As-Measured Acoustic Data
Airchime K-5-LAR24, Cab Roof-Installed, GP-40 Locomotive
135 psi / 111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	111.3
2	200	0	105.1
3	400	0	98.8
4	100	45	108.2
5	200	45	102.9
6	100	90	103.8
7	200	90	96.9
8	400	90	88.3
9	100	135	104.7
10	200	135	100.9
11	100	180	93.8
12	200	180	90.4
13	100	270	105.7
14	200	270	98.8
1C	130	0	110.7
2C	230	0	104.5
15O	Cab, Windows Open		104.0
15C	Cab, Windows Closed		97.7

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	67.1	61.1	68.2	59.1	47.6	49.5	59.2	58.0	90.6	98.6	95.7	99.4
3	400	0	62.5	56.9	61.4	51.0	42.2	42.5	49.0	47.5	79.1	88.4	85.4	91.5
8	400	90	68.8	60.6	69.4	60.4	48.2	45.0	45.8	44.7	79.5	84.1	81.3	83.6

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
97.7	93.6	93.7	93.2	95.1	92.5	91.8	88.8	85.9	82.4	78.5	73.8
91.8	89.2	88.3	87.0	90.3	88.0	85.1	81.4	77.6	72.2	65.9	58.0
82.8	77.7	75.9	74.0	73.3	70.8	70.1	62.6	58.5	50.1	42.3	31.1

Table B -10
As-Measured Acoustic Data
Airchime K-5-LA, Cab Roof-Installed, GP-40 Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	113.1
2	200	0	107.0
3	400	0	99.4
4	100	45	109.9
5	200	45	104.5
6	100	90	105.9
7	200	90	99.2
8	400	90	91.2
9	100	135	104.0
10	200	135	99.5
11	100	180	92.5
12	200	180	88.9
13	100	270	105.8
14	200	270	99.1
1C	130	0	112.5
2C	230	0	106.1
15O	Cab, Windows Open		104.9
15C	Cab, Windows Closed		

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	66.9	61.1	68.1	59.0	52.5	50.8	59.1	61.4	90.5	99.2	99.1	98.3
3	400	0	62.3	57.1	61.7	51.2	47.8	44.0	49.9	51.6	79.6	89.4	88.1	89.5
8	400	90	68.6	60.8	70.0	60.6	49.6	45.1	47.4	45.5	80.2	85.0	85.6	85.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
101.8	96.2	96.2	95.5	95.8	92.8	93.7	91.1	88.7	84.1	81.1	76.0
94.4	89.7	88.3	87.8	90.0	88.5	85.9	81.9	78.1	72.8	67.0	59.4
86.5	78.7	78.9	78.6	78.8	73.0	73.9	68.4	63.3	56.3	47.9	36.9

Table B -11
As-Measured Acoustic Data
Airchime K-5-LA, Cab Roof-Installed, GP-40 Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	111.2
2	200	0	106.3
3	400	0	97.8
4	100	45	107.5
5	200	45	102.7
6	100	90	104.0
7	200	90	96.6
8	400	90	86.7
9	100	135	103.0
10	200	135	98.4
11	100	180	92.6
12	200	180	88.6
13	100	270	105.2
14	200	270	97.8
1C	130	0	110.6
2C	230	0	105.6
15O	Cab, Windows Open		104.7
15C	Cab, Windows Closed		96.1

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	67.0	61.2	68.1	59.1	51.6	50.2	57.7	57.9	89.3	98.1	96.4	99.2
3	400	0	62.4	56.3	61.4	51.3	46.5	43.7	49.3	48.4	76.9	88.3	85.0	89.4
8	400	90	68.1	60.2	69.3	59.9	47.2	44.9	43.9	42.8	78.8	83.1	81.4	79.8

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
101.0	94.3	95.1	96.8	95.0	93.0	91.0	88.9	86.8	82.7	78.5	74.0
92.2	86.5	86.5	88.1	87.8	86.7	83.9	80.3	76.7	71.5	65.4	57.4
81.5	73.1	73.6	75.3	72.9	66.9	67.5	62.2	57.1	48.9	40.8	31.0

Table B -12
As-Measured Acoustic Data
Airchime K-5-LA, Cab Roof-Installed, GP-40 Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	97.1
2	200	0	91.9
3	400	0	83.4
4	100	45	94.5
5	200	45	89.8
6	100	90	92.1
7	200	90	84.6
8	400	90	72.3
9	100	135	90.7
10	200	135	85.6
11	100	180	80.4
12	200	180	75.4
13	100	270	91.2
14	200	270	83.7
1C	130	0	96.4
2C	230	0	91.5
15O	Cab, Windows Open		
15C	Cab, Windows Closed		83.3

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	67.4	61.1	67.7	58.2	44.1	46.6	44.1	46.5	85.3	79.3	87.8	86.9
3	400	0	62.9	56.6	60.8	50.4	39.6	40.5	36.5	36.6	72.2	69.0	75.6	77.1
8	400	90	68.3	59.6	68.3	58.4	43.4	42.1	35.5	34.4	74.6	65.7	70.4	64.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
80.0	84.8	82.9	79.6	77.2	72.9	69.7	65.7	61.1	54.3	46.5	36.5
71.1	78.3	76.2	70.4	70.6	66.7	61.6	55.9	50.4	41.1	30.4	20.7
57.0	59.4	58.3	49.5	46.4	39.5	34.5	32.5	26.5	22.2	19.1	18.7

Table B -13
As-Measured Acoustic Data
Leslie RS-3L, Cab Roof-Installed, GP-40 Locomotive
135 psi / 111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.4
2	200	0	106.1
3	400	0	100.6
4	100	45	106.9
5	200	45	102.2
6	100	90	103.3
7	200	90	97.3
8	400	90	85.6
9	100	135	100.8
10	200	135	96.6
11	100	180	89.9
12	200	180	84.8
13	100	270	103.3
14	200	270	97.3
1C	130	0	111.8
2C	230	0	105.5
15O	Cab, Windows Open		106.1
15C	Cab, Windows Closed		98.9

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	67.2	60.8	68.1	58.7	47.8	51.6	52.5	87.6	92.7	93.4	97.0	97.5
3	400	0	62.7	56.4	61.2	51.1	42.9	44.9	44.3	75.2	82.1	83.0	87.4	90.4
8	400	90	68.0	60.0	69.1	59.4	46.6	44.2	42.4	74.6	80.3	78.1	78.6	79.6

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
97.1	97.4	97.5	95.6	96.0	93.2	92.6	89.9	87.1	83.9	80.1	75.5
90.8	92.4	92.0	90.7	92.7	89.5	85.5	82.4	77.8	72.5	66.6	59.3
74.9	76.6	77.5	73.7	73.9	71.3	62.4	59.9	53.6	45.5	37.8	27.5

Table B -14
As-Measured Acoustic Data
Leslie RS-3L, Cab Roof-Installed, GP-40 Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	98.1
2	200	0	94.9
3	400	0	84.6
4	100	45	96.4
5	200	45	90.6
6	100	90	92.5
7	200	90	83.6
8	400	90	73.6
9	100	135	92.6
10	200	135	86.3
11	100	180	84.1
12	200	180	79.7
13	100	270	95.4
14	200	270	86.5
1C	130	0	97.5
2C	230	0	93.8
15O	Cab, Windows Open		97.7
15C	Cab, Windows Closed		93.9

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	66.8	61.0	67.5	58.0	44.5	47.4	44.1	83.3	86.3	77.4	93.6	88.2
3	400	0	62.3	56.2	60.9	50.3	39.2	40.7	36.2	70.4	72.8	65.6	82.2	78.5
8	400	90	67.9	60.2	68.5	58.4	44.8	43.4	37.0	71.3	73.6	61.4	73.1	65.8

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
89.7	85.6	79.8	78.0	75.5	71.9	68.9	63.9	59.6	54.7	47.8	39.3
79.4	75.9	71.2	69.6	68.5	65.7	60.6	53.8	48.0	40.8	31.5	21.6
62.6	58.7	51.6	47.9	45.1	41.7	32.9	30.6	24.7	20.1	19.8	19.6

Table B -15
As-Measured Acoustic Data
Leslie RS-3L, Front Hood-Installed, GP-40 Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	113.3
2	200	0	106.1
3	400	0	99.0
4	100	45	109.3
5	200	45	103.3
6	100	90	104.7
7	200	90	97.2
8	400	90	91.2
9	100	135	101.4
10	200	135	94.1
11	100	180	90.6
12	200	180	84.4
13	100	270	103.8
14	200	270	95.6
1C	130	0	112.3
2C	230	0	105.2
15O	Cab, Windows Open		
15C	Cab, Windows Closed		95.3

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.7	60.9	67.8	58.3	46.1	53.1	56.1	89.6	84.5	100.1	96.9	98.2
3	400	0	64.3	54.5	60.1	51.2	40.9	47.4	48.7	77.9	75.4	92.9	89.4	89.4
7	200	90	75.0	65.2	77.6	68.3	54.2	52.2	51.2	82.1	86.3	89.9	86.9	92.4
8	400	90	69.9	61.1	71.8	62.7	46.5	45.6	42.9	73.8	71.0	80.2	78.6	86.2

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
91.8	93.4	97.9	96.6	97.7	92.1	93.2	88.2	87.9	83.8	81.1	76.7
87.5	86.2	85.4	88.8	92.5	89.8	83.0	77.9	79.3	73.8	67.9	62.2
90.7	89.8	87.0	84.3	84.3	82.1	76.3	73.8	69.7	64.1	58.8	52.2
85.2	84.5	82.9	75.8	77.5	77.4	67.8	65.0	59.7	52.3	45.9	36.8

Table B -16
As-Measured Acoustic Data
Leslie RS-3L, Front Hood-Installed, GP-40 Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	111.7
2	200	0	104.9
3	400	0	97.6
4	100	45	108.1
5	200	45	102.2
6	100	90	103.2
7	200	90	95.3
8	400	90	89.1
9	100	135	101.1
10	200	135	93.6
11	100	180	89.5
12	200	180	82.8
13	100	270	102.6
14	200	270	94.2
1C	130	0	110.9
2C	230	0	104.0
15O	Cab, Windows Open		105.7
15C	Cab, Windows Closed		93.0

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.3	60.5	67.9	58.0	46.5	51.4	55.1	90.0	82.4	99.0	97.9	94.3
3	400	0	63.8	54.2	60.3	51.3	41.8	44.8	46.8	76.9	73.2	92.7	91.1	86.0
7	200	90	74.6	65.0	77.9	68.7	54.2	52.1	49.7	74.6	84.0	88.6	89.2	90.5
8	400	90	69.4	61.2	72.1	63.0	46.9	45.6	41.5	73.4	69.2	79.5	80.7	84.8

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
90.2	92.0	96.7	97.6	94.9	89.9	91.4	85.6	86.2	82.5	78.4	74.1
87.0	84.6	84.9	90.2	90.0	83.8	78.6	80.6	76.1	71.2	66.2	59.7
89.5	87.5	83.8	82.2	80.5	74.6	71.7	66.4	63.4	59.6	54.7	47.8
83.8	82.3	79.1	73.3	73.6	69.7	62.4	58.9	54.2	48.4	41.6	32.4

Table B -17
As-Measured Acoustic Data
Leslie RS-3L, Front Hood-Installed, GP-40 Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	94.9
2	200	0	91.2
3	400	0	83.8
4	100	45	94.4
5	200	45	86.7
6	100	90	92.4
7	200	90	82.6
8	400	90	75.3
9	100	135	91.2
10	200	135	82.7
11	100	180	79.2
12	200	180	73.2
13	100	270	91.2
14	200	270	81.5
1C	130	0	95.4
2C	230	0	90.3
15O	Cab, Windows Open		95.1
15C	Cab, Windows Closed		90.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.4	60.9	67.6	58.2	43.3	47.8	44.5	84.6	80.7	88.1	92.6	69.7
3	400	0	63.8	54.6	59.9	50.9	38.9	42.0	36.2	72.7	71.1	80.8	85.1	61.5
7	200	90	74.5	65.1	77.3	67.2	52.4	52.5	46.1	47.9	77.0	76.1	82.7	75.7
8	400	90	69.4	61.2	71.5	61.6	45.3	45.4	36.7	69.3	62.7	66.9	74.5	71.0

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
78.7	76.4	71.0	70.4	67.5	64.5	63.4	51.4	49.4	46.3	40.7	31.2
74.8	65.9	61.3	63.5	63.0	61.2	51.3	42.9	41.2	34.2	29.5	21.6
74.5	66.9	57.5	51.2	52.5	47.9	43.0	43.8	39.7	37.1	33.4	30.6
69.0	62.6	53.5	45.9	43.6	42.5	34.2	36.0	31.0	25.7	22.1	20.7

Table B -18
As-Measured Acoustic Data
Airchime K-5-LA, Front Hood-Installed, GP-40 Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	114.5
2	200	0	106.3
3	400	0	100.1
4	100	45	111.5
5	200	45	104.0
6	100	90	106.4
7	200	90	98.7
8	400	90	92.2
9	100	135	104.3
10	200	135	99.4
11	100	180	91.2
12	200	180	85.6
13	100	270	106.7
14	200	270	99.0
1C	130	0	113.3
2C	230	0	105.9
15O	Cab, Windows Open		108.7
15C	Cab, Windows Closed		98.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.8	61.2	67.7	58.5	51.8	52.7	60.5	62.7	90.9	96.8	95.9	99.5
3	400	0	64.4	54.8	60.2	51.7	47.1	46.9	51.0	52.8	81.9	90.5	89.1	92.2
7	200	90	75.1	65.1	77.5	68.6	56.0	52.4	54.4	81.0	84.5	85.5	90.5	95.6
8	400	90	69.9	61.0	71.6	63.0	49.6	45.9	46.0	42.8	70.6	79.1	81.2	89.4

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
98.3	95.4	95.4	96.9	97.5	90.8	94.4	88.9	89.2	84.4	81.6	77.1
95.0	88.3	84.4	89.3	91.8	89.5	83.1	79.5	80.4	73.6	69.1	62.6
95.0	87.4	86.0	80.1	85.3	81.0	80.4	76.3	73.8	68.6	62.4	55.9
88.4	82.4	81.3	77.1	73.5	75.1	70.7	66.8	62.0	55.9	48.1	38.8

Table B -19
As-Measured Acoustic Data
Airchime K-5-LA, Front Hood-Installed, GP-40 Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.4
2	200	0	104.6
3	400	0	98.5
4	100	45	109.6
5	200	45	102.2
6	100	90	102.5
7	200	90	95.4
8	400	90	89.4
9	100	135	103.1
10	200	135	97.5
11	100	180	89.5
12	200	180	83.5
13	100	270	102.9
14	200	270	96.7
1C	130	0	111.4
2C	230	0	104.2
15O	Cab, Windows Open		105.8
15C	Cab, Windows Closed		94.6

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.5	61.1	67.9	58.4	47.7	50.6	53.3	58.1	90.4	96.2	94.1	91.0
3	400	0	64.1	54.8	60.4	51.4	42.8	44.4	45.4	48.6	82.2	90.2	87.9	84.0
7	200	90	74.7	64.8	77.6	68.7	55.6	52.6	50.4	78.2	83.8	84.2	87.7	90.5
8	400	90	69.5	61.0	71.8	63.2	48.5	45.9	42.0	38.1	70.0	78.3	79.1	85.1

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
95.7	92.0	95.6	96.6	96.5	89.5	92.1	86.2	87.2	82.4	78.6	74.2
93.2	85.0	84.0	89.4	91.3	86.9	80.2	80.0	78.7	70.8	67.6	59.9
92.6	84.3	80.2	79.3	82.1	78.2	76.7	73.6	70.6	64.3	58.1	52.8
86.5	79.2	76.1	76.7	70.4	72.1	66.8	63.3	57.8	51.5	43.7	35.7

Table B -20
As-Measured Acoustic Data
Airchime K-5-LA, Front Hood-Installed, GP-40 Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	95.4
2	200	0	88.4
3	400	0	81.4
4	100	45	93.8
5	200	45	85.7
6	100	90	90.7
7	200	90	81.8
8	400	90	74.8
9	100	135	89.2
10	200	135	82.6
11	100	180	78.2
12	200	180	71.7
13	100	270	89.7
14	200	270	81.1
1C	130	0	95.2
2C	230	0	87.6
15O	Cab, Windows Open		95.9
15C	Cab, Windows Closed		81.0

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.5	60.8	67.7	58.1	43.1	47.9	44.6	46.9	84.9	83.6	82.2	84.7
3	400	0	63.8	54.5	59.8	50.8	38.8	42.2	36.8	37.9	75.6	77.7	75.5	77.2
7	200	90	74.6	65.1	77.3	66.8	52.8	52.9	47.0	49.5	79.8	63.8	78.9	78.8
8	400	90	69.4	61.2	71.4	61.4	45.9	45.0	37.6	33.8	67.7	62.3	69.7	72.2

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
74.3	78.8	80.6	75.4	72.1	63.2	66.0	55.4	56.0	50.1	42.8	32.7
73.5	73.6	69.4	66.8	66.7	62.2	56.7	45.2	46.1	41.0	27.7	21.4
74.6	70.0	71.4	57.2	57.4	49.5	44.6	45.7	42.2	38.7	32.3	26.9
67.2	64.7	67.4	56.9	46.7	41.1	40.0	38.5	34.2	27.1	21.3	20.3

Table B -21
As-Measured Acoustic Data
Airchime K-5-LA, Knuckle-Installed, GP-40 Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.0
2	200	0	104.7
3	400	0	96.3
4	100	45	111.8
5	200	45	103.2
6	100	90	104.8
7	200	90	96.4
8	400	90	88.3
9	100	135	98.9
10	200	135	91.9
11	100	180	82.7
12	200	180	75.6
13	100	270	104.7
14	200	270	97.0
1C	130	0	112.2
2C	230	0	104.4
15O	Cab, Windows Open		99.4
15C	Cab, Windows Closed		91.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.8	60.7	68.0	59.1	48.3	49.1	53.9	56.9	88.1	92.0	89.8	96.2
3	400	0	64.2	54.8	60.5	51.5	42.9	43.8	44.6	46.5	76.0	84.9	80.0	87.4
7	200	90	74.7	64.9	77.6	68.1	56.7	52.7	54.7	81.3	82.0	87.3	88.2	89.8
8	400	90	69.5	60.7	71.7	62.5	49.5	45.7	46.2	43.8	68.9	76.1	75.7	80.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
94.9	90.9	89.9	93.1	96.8	97.7	93.7	84.6	87.7	85.3	78.4	76.6
87.0	81.7	81.1	83.9	87.5	89.2	87.3	81.9	74.0	72.7	68.8	60.0
90.6	83.2	85.7	86.4	88.0	81.3	78.0	71.1	73.9	68.2	61.4	56.5
82.4	74.6	77.2	78.0	80.4	75.9	76.4	70.1	61.7	55.5	50.9	40.2

Table B -22
As-Measured Acoustic Data
Airchime K-5-LA, Knuckle-Installed, GP-40 Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	110.3
2	200	0	103.6
3	400	0	95.0
4	100	45	110.8
5	200	45	102.2
6	100	90	103.3
7	200	90	95.3
8	400	90	87.6
9	100	135	96.9
10	200	135	89.6
11	100	180	80.3
12	200	180	73.7
13	100	270	102.5
14	200	270	94.8
1C	130	0	110.7
2C	230	0	103.4
15O	Cab, Windows Open		97.7
15C	Cab, Windows Closed		90.3

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.6	61.0	68.2	59.4	46.7	48.3	51.1	53.9	87.7	91.8	89.0	87.6
3	400	0	64.1	54.9	61.0	52.2	41.9	42.9	40.7	43.6	76.2	84.7	79.3	81.2
7	200	90	74.7	64.8	77.7	68.4	56.4	53.0	53.1	78.9	81.7	86.4	87.6	88.8
8	400	90	69.6	60.7	72.0	63.0	49.2	45.7	44.7	40.3	68.6	75.6	75.8	79.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
93.7	89.1	86.8	92.3	95.2	98.0	92.9	82.7	86.1	83.3	76.9	74.9
85.2	79.1	77.2	83.2	85.7	89.3	85.9	78.3	72.9	71.6	65.1	57.2
89.4	81.2	85.3	85.6	86.8	78.9	74.9	69.3	71.9	64.0	59.5	53.1
81.7	73.0	77.7	78.0	80.0	74.3	74.0	66.5	57.5	55.0	48.3	37.2

Table B -23
As-Measured Acoustic Data
Airchime K-5-LA, Knuckle-Installed, GP-40 Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	93.7
2	200	0	85.9
3	400	0	76.5
4	100	45	95.5
5	200	45	85.2
6	100	90	88.2
7	200	90	78.7
8	400	90	69.7
9	100	135	84.0
10	200	135	76.7
11	100	180	71.2
12	200	180	61.4
13	100	270	88.7
14	200	270	80.7
1C	130	0	93.9
2C	230	0	85.5
15O	Cab, Windows Open		90.0
15C	Cab, Windows Closed		77.1

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.6	60.6	67.9	58.8	43.2	47.6	44.1	46.9	82.5	77.3	78.9	82.9
3	400	0	64.0	54.7	60.5	51.3	39.0	42.2	37.3	39.0	70.0	69.3	68.6	73.8
7	200	90	74.5	65.2	77.4	66.6	52.4	53.1	47.1	49.9	76.9	71.4	76.0	73.0
8	400	90	69.4	60.8	71.6	61.1	45.6	45.3	38.6	34.9	63.6	61.7	65.3	64.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
75.5	77.3	73.1	73.8	73.6	70.8	65.6	52.9	55.1	52.5	41.9	32.6
66.8	67.1	66.0	63.8	63.5	62.5	58.9	48.8	41.5	38.3	29.0	19.8
71.1	67.1	68.8	64.3	61.6	49.9	45.8	46.4	45.1	40.7	36.9	32.0
63.4	59.0	61.3	56.6	54.8	44.0	42.8	40.2	33.8	29.7	26.0	21.4

Table B -24
As-Measured Acoustic Data
Leslie RS-3L, Knuckle-Installed, GP-40 Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.9
2	200	0	105.1
3	400	0	96.1
4	100	45	109.2
5	200	45	100.9
6	100	90	103.1
7	200	90	97.0
8	400	90	89.1
9	100	135	96.3
10	200	135	91.2
11	100	180	81.1
12	200	180	76.0
13	100	270	102.4
14	200	270	95.4
1C	130	0	112.3
2C	230	0	104.8
15O	Cab, Windows Open		96.6
15C	Cab, Windows Closed		86.4

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.7	60.6	68.1	59.2	45.8	49.9	49.5	88.8	93.3	94.9	91.0	95.1
3	400	0	64.1	54.9	60.6	51.3	41.4	44.8	41.6	79.0	79.7	85.7	82.2	85.0
7	200	90	74.5	65.0	77.5	67.9	55.4	52.1	52.0	85.0	86.3	90.8	85.1	87.2
8	400	90	69.4	60.6	71.7	62.1	47.5	45.5	44.5	72.8	72.6	77.3	72.7	77.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
92.4	91.7	92.3	95.6	98.7	96.7	91.2	85.6	87.9	83.0	79.2	75.4
84.1	80.7	82.7	85.9	89.4	88.5	85.3	78.4	73.2	72.9	66.8	58.9
83.6	86.3	89.2	90.6	86.3	85.0	77.2	69.8	71.3	65.8	58.2	54.6
75.3	77.7	80.9	83.4	79.0	79.0	75.0	69.5	62.7	50.3	47.6	40.1

Table B -25
As-Measured Acoustic Data
Leslie RS-3L, Knuckle-Installed, GP-40 Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	110.5
2	200	0	102.5
3	400	0	94.1
4	100	45	106.8
5	200	45	97.9
6	100	90	100.2
7	200	90	93.3
8	400	90	84.3
9	100	135	94.4
10	200	135	88.5
11	100	180	80.7
12	200	180	73.4
13	100	270	99.7
14	200	270	92.2
1C	130	0	110.2
2C	230	0	102.3
15O	Cab, Windows Open		94.4
15C	Cab, Windows Closed		83.0

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.5	60.6	68.2	59.0	45.7	48.5	48.9	89.1	90.9	93.5	92.0	92.6
3	400	0	63.9	54.9	60.9	51.3	41.1	42.9	41.2	78.5	78.5	84.6	83.7	83.0
7	200	90	74.3	65.2	77.6	67.6	54.5	52.3	51.3	77.1	84.7	89.0	86.6	84.9
8	400	90	69.1	60.7	71.7	61.8	46.9	45.2	42.7	73.9	71.7	76.2	73.8	75.2

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
90.8	89.2	90.1	94.1	95.0	93.4	88.0	83.4	85.4	79.0	76.8	71.4
82.9	79.5	80.8	84.8	87.2	85.7	82.3	73.0	73.1	70.0	62.3	56.1
81.9	83.1	86.1	84.0	81.1	77.1	69.5	62.5	63.5	60.5	52.2	47.7
73.0	74.7	77.6	76.4	73.6	70.3	67.1	62.0	55.9	46.6	40.0	32.3

Table B -26
As-Measured Acoustic Data
Leslie RS-3L, Knuckle-Installed, GP-40 Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	96.3
2	200	0	87.8
3	400	0	78.9
4	100	45	94.1
5	200	45	83.4
6	100	90	89.9
7	200	90	80.8
8	400	90	70.1
9	100	135	83.3
10	200	135	75.1
11	100	180	73.7
12	200	180	65.5
13	100	270	89.8
14	200	270	83.0
1C	130	0	96.3
2C	230	0	87.7
15O	Cab, Windows Open		88.1
15C	Cab, Windows Closed		74.9

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	68.5	60.7	68.2	59.0	43.2	47.9	44.0	83.9	82.4	84.4	86.9	76.7
3	400	0	64.0	54.8	61.1	51.7	38.6	42.0	36.0	74.0	71.4	76.2	78.5	66.9
7	200	90	74.3	65.1	77.4	66.6	52.5	52.5	46.1	52.5	75.8	78.4	80.6	70.5
8	400	90	69.1	60.7	71.6	60.9	45.3	45.1	37.4	67.8	62.5	65.3	68.7	63.3

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
79.4	76.1	67.9	70.9	70.7	69.4	61.9	49.8	49.7	46.1	43.1	32.5
70.9	62.9	59.0	61.3	62.5	62.7	54.8	39.7	39.5	34.3	27.9	20.7
69.5	67.5	61.1	60.3	56.4	52.5	43.0	45.3	40.7	36.8	34.8	31.0
61.5	59.1	53.3	53.2	49.3	46.7	39.7	38.2	31.9	26.1	23.0	20.9

Table B -27
As-Measured Acoustic Data
Airchime K-5-LA, Knuckle-Installed, SD60MAC Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.0
2	200	0	103.6
3	400	0	92.0
4	100	45	110.1
5	200	45	101.6
6	100	90	103.1
7	200	90	94.8
8	400	90	83.9
9	100	135	97.2
10	200	135	88.6
11	100	180	79.0
12	200	180	71.8
13	100	270	103.2
14	200	270	95.4
1C	130	0	112.0
2C	230	0	103.5
15O	Cab, Windows Open		93.2
15C	Cab, Windows Closed		80.7

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	66.2	64.9	59.4	50.6	48.2	45.4	50.5	54.8	89.2	86.0	95.9	83.6
3	400	0	63.5	61.1	59.3	50.0	43.1	42.7	44.2	45.1	74.9	78.3	83.6	73.1
7	200	90	70.0	70.4	65.6	60.9	57.5	52.7	54.5	51.7	85.9	78.0	85.5	88.7
8	400	90	64.8	66.1	62.4	56.1	50.3	44.3	46.0	43.7	75.5	69.3	73.6	77.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
96.3	89.1	87.4	91.0	93.7	95.1	94.7	91.3	86.4	81.8	78.2	73.7
86.7	78.5	76.5	80.5	81.8	82.7	80.7	78.4	76.1	70.9	64.7	57.8
89.1	80.3	82.7	83.4	86.4	81.9	81.9	76.0	69.5	62.5	59.1	54.4
79.5	70.4	72.4	72.1	74.4	70.1	69.1	63.9	59.6	52.5	45.0	35.5

Table B -28
As-Measured Acoustic Data
Airchime K-5-LA, Knuckle-Installed, SD60MAC Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	110.9
2	200	0	102.8
3	400	0	93.1
4	100	45	109.3
5	200	45	100.8
6	100	90	102.4
7	200	90	93.7
8	400	90	81.1
9	100	135	97.0
10	200	135	87.4
11	100	180	78.5
12	200	180	71.1
13	100	270	103.2
14	200	270	95.5
1C	130	0	111.0
2C	230	0	103.0
15O	Cab, Windows Open		
15C	Cab, Windows Closed		

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	69.4	66.8	59.5	51.0	47.7	46.1	49.3	52.8	88.3	85.5	92.5	86.2
3	400	0	65.1	61.9	59.1	50.0	43.0	42.9	42.8	43.8	73.6	78.9	80.4	77.1
7	200	90	74.6	73.0	66.3	61.2	57.0	53.1	53.0	50.4	85.4	77.9	82.2	87.2
8	400	90	69.5	68.9	62.8	56.6	50.0	45.1	44.6	43.0	75.3	69.5	70.2	75.8

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
96.4	88.7	87.4	91.1	93.9	94.2	93.6	89.3	82.7	78.6	76.8	71.9
87.6	78.3	77.2	81.7	83.7	84.5	82.7	80.0	77.1	70.5	63.5	55.8
89.1	78.3	80.8	82.3	84.4	80.6	81.0	76.4	73.0	65.5	60.1	54.2
78.1	66.9	68.0	68.1	68.5	63.5	62.4	56.6	52.4	44.7	37.2	29.2

Table B -29
As-Measured Acoustic Data
Airchime K-5-LA, Knuckle-Installed, SD60MAC Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	97.1
2	200	0	88.4
3	400	0	78.3
4	100	45	96.8
5	200	45	86.7
6	100	90	91.1
7	200	90	81.7
8	400	90	69.9
9	100	135	85.6
10	200	135	76.2
11	100	180	70.5
12	200	180	62.7
13	100	270	92.3
14	200	270	84.2
1C	130	0	97.6
2C	230	0	88.1
15O	Cab, Windows Open		
15C	Cab, Windows Closed		

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	61.6	60.2	57.7	48.7	42.5	41.1	42.7	45.0	84.6	77.0	87.0	82.6
3	400	0	59.8	57.2	58.2	49.3	40.7	39.7	38.4	37.2	69.1	68.9	75.0	73.5
7	200	90	64.8	64.8	62.4	58.1	54.0	49.1	46.7	44.7	81.2	69.0	74.0	80.1
8	400	90	59.6	60.4	59.9	53.2	45.5	40.4	38.3	39.7	71.1	58.8	61.9	67.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
78.8	76.3	77.7	73.7	72.9	71.3	71.3	61.6	56.8	54.0	48.6	37.5
70.0	67.4	69.1	64.1	64.2	63.3	62.9	53.4	49.1	42.6	33.3	22.4
72.2	68.2	72.1	61.3	61.2	53.2	53.2	49.9	49.5	46.4	43.4	38.4
61.2	56.8	58.2	48.5	46.6	38.3	37.9	33.1	32.1	28.3	24.1	21.0

Table B -30
As-Measured Acoustic Data
Airchime K-5-LA, Front Hood-Installed, SD60MAC Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	113.2
2	200	0	105.6
3	400	0	99.5
4	100	45	112.5
5	200	45	105.1
6	100	90	107.0
7	200	90	100.0
8	400	90	91.1
9	100	135	102.4
10	200	135	97.7
11	100	180	84.9
12	200	180	84.2
13	100	270	108.2
14	200	270	99.6
1C	130	0	112.1
2C	230	0	105.5
15O	Cab, Windows Open		
15C	Cab, Windows Closed		

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	72.0	73.6	62.7	51.8	56.4	52.1	59.9	61.1	92.0	86.6	99.6	99.4
3	400	0	67.2	67.7	59.9	49.6	51.8	47.7	50.2	50.8	80.3	80.1	90.9	92.9
7	200	90	76.6	81.0	71.2	61.9	62.3	56.7	58.2	55.9	90.3	91.7	88.5	96.7
8	400	90	70.6	75.6	66.2	56.3	55.7	49.3	50.3	49.0	80.6	84.9	79.7	86.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
97.6	93.1	94.3	94.6	96.3	91.6	93.0	90.1	86.8	84.0	80.3	75.8
93.1	88.2	85.5	87.0	90.2	90.2	86.7	81.1	78.2	74.1	69.0	61.8
96.6	86.6	89.9	82.6	83.6	77.9	81.9	77.2	72.2	68.1	62.0	55.6
86.8	77.7	80.1	76.0	79.7	74.3	73.2	68.8	63.7	57.0	48.8	39.1

Table B -31
As-Measured Acoustic Data
Airchime K-5-LA, Front Hood-Installed, SD60MAC Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	111.3
2	200	0	104.2
3	400	0	97.9
4	100	45	108.9
5	200	45	102.3
6	100	90	103.3
7	200	90	96.6
8	400	90	87.3
9	100	135	101.6
10	200	135	96.3
11	100	180	85.8
12	200	180	84.1
13	100	270	107.7
14	200	270	97.9
1C	130	0	110.3
2C	230	0	104.2
15O	Cab, Windows Open		104.2
15C	Cab, Windows Closed		90.0

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	64.6	62.2	58.2	49.8	49.2	47.5	54.5	57.0	90.6	85.9	97.0	98.6
3	400	0	61.6	58.6	58.3	49.0	45.5	44.2	46.8	47.0	78.8	79.0	87.9	90.8
7	200	90	69.5	68.0	63.9	59.6	54.8	51.8	50.2	51.5	89.5	91.3	85.7	85.1
8	400	90	64.4	63.1	60.7	54.6	47.2	43.7	42.5	44.0	80.0	84.4	77.3	74.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
96.9	91.9	94.9	95.0	93.0	89.8	89.3	88.7	83.7	81.4	77.0	72.5
91.8	87.1	87.7	87.0	87.0	88.1	84.8	80.9	77.2	71.8	65.9	58.2
93.7	84.4	87.4	83.4	83.6	75.0	76.2	72.6	67.8	62.7	57.1	51.7
83.7	75.1	76.7	74.3	75.8	68.3	66.7	62.0	56.6	49.5	41.8	33.1

Table B -32
As-Measured Acoustic Data
Airchime K-5-LA, Front Hood-Installed, SD60MAC Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	97.5
2	200	0	91.7
3	400	0	83.8
4	100	45	95.9
5	200	45	88.4
6	100	90	92.8
7	200	90	84.7
8	400	90	74.1
9	100	135	88.7
10	200	135	82.9
11	100	180	74.0
12	200	180	72.6
13	100	270	95.9
14	200	270	85.5
1C	130	0	97.0
2C	230	0	91.9
15O	Cab, Windows Open		89.7
15C	Cab, Windows Closed		81.2

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	61.9	60.0	58.0	49.2	45.1	44.0	44.7	47.1	86.0	73.3	87.8	89.9
3	400	0	60.2	57.4	58.7	49.5	43.0	42.7	40.7	40.3	73.3	66.2	77.9	82.0
7	200	90	64.7	64.5	61.2	57.7	53.7	49.8	48.2	47.6	84.7	76.1	77.9	81.8
8	400	90	59.5	59.8	59.2	52.8	47.2	43.1	42.0	42.6	75.3	69.2	67.3	70.0

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
80.4	79.8	82.2	76.6	75.7	68.0	66.3	61.6	57.7	53.2	46.0	36.7
74.3	74.4	75.5	68.2	67.4	64.1	62.1	55.1	51.0	44.2	35.0	24.0
74.3	71.2	76.6	65.0	57.8	50.2	49.4	47.2	46.6	44.4	41.3	36.5
62.6	60.0	62.8	52.7	48.3	40.8	38.3	31.7	30.4	25.4	21.2	19.6

Table B -33
As-Measured Acoustic Data
Airchime K-5-LA, Cab Roof-Installed, SD60MAC Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.9
2	200	0	105.4
3	400	0	99.2
4	100	45	110.8
5	200	45	104.5
6	100	90	105.9
7	200	90	100.0
8	400	90	89.7
9	100	135	104.2
10	200	135	100.2
11	100	180	95.1
12	200	180	92.3
13	100	270	105.9
14	200	270	99.6
1C	130	0	111.7
2C	230	0	105.6
15O	Cab, Windows Open		99.4
15C	Cab, Windows Closed		92.5

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	72.4	73.7	63.2	52.1	53.8	51.7	55.3	57.8	88.7	95.9	96.6	86.7
3	400	0	67.6	67.9	60.6	50.0	49.2	47.0	47.0	48.4	77.6	88.0	87.3	80.6
7	200	90	76.7	80.3	70.8	61.8	61.5	56.6	58.5	56.2	88.2	90.9	91.1	95.9
8	400	90	70.8	74.9	65.9	56.2	55.1	49.0	50.6	49.7	80.2	84.5	82.2	85.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
97.1	94.8	95.7	95.5	97.6	92.7	92.7	89.5	87.1	83.8	79.9	75.6
92.8	89.9	87.9	88.1	90.5	89.1	86.6	82.7	79.3	74.4	68.8	61.5
97.1	87.6	86.8	84.0	85.2	81.6	80.4	76.2	72.7	68.2	62.4	55.7
85.8	76.3	76.4	73.7	74.7	69.2	68.2	63.8	59.4	52.8	44.2	34.8

Table B -34
As-Measured Acoustic Data
Airchime K-5-LA, Cab Roof-Installed, SD60MAC Locomotive
111 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	111.9
2	200	0	103.7
3	400	0	98.3
4	100	45	108.1
5	200	45	102.2
6	100	90	103.2
7	200	90	98.1
8	400	90	88.1
9	100	135	103.7
10	200	135	99.6
11	100	180	92.7
12	200	180	90.8
13	100	270	104.1
14	200	270	97.8
1C	130	0	110.0
2C	230	0	104.1
15O	Cab, Windows Open		98.4
15C	Cab, Windows Closed		90.8

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	71.6	71.5	60.6	52.4	50.3	49.2	52.1	53.9	88.0	95.2	93.8	92.3
3	400	0	66.8	65.7	59.2	50.6	46.1	44.8	45.6	45.5	77.0	87.6	84.9	84.7
7	200	90	76.3	77.8	68.3	61.8	58.2	54.5	54.3	53.6	87.8	90.6	89.2	89.4
8	400	90	69.9	72.4	63.8	56.4	51.7	47.2	46.6	47.1	79.9	84.3	80.7	79.7

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
94.5	92.1	96.0	95.3	92.5	92.0	91.1	87.0	85.3	81.7	77.7	73.3
91.7	87.9	88.4	88.7	88.4	88.9	84.8	80.9	77.3	72.2	66.5	59.0
96.1	86.7	83.2	84.3	84.5	79.1	78.0	73.7	70.0	65.0	58.9	53.2
85.4	75.5	72.9	73.9	73.2	68.2	67.0	62.4	57.8	50.9	42.0	33.4

Table B -35
As-Measured Acoustic Data
Airchime K-5-LA, Cab Roof-Installed, SD60MAC Locomotive
96 dB(A)

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	96.6
2	200	0	91.6
3	400	0	83.6
4	100	45	95.9
5	200	45	89.8
6	100	90	93.5
7	200	90	86.4
8	400	90	75.5
9	100	135	92.2
10	200	135	87.4
11	100	180	84.3
12	200	180	80.7
13	100	270	95.7
14	200	270	87.9
1C	130	0	95.6
2C	230	0	91.6
15O	Cab, Windows Open		89.8
15C	Cab, Windows Closed		81.0

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	62.1	60.4	58.5	50.3	45.1	43.6	43.4	46.1	82.7	78.1	86.4	88.6
3	400	0	60.3	57.8	58.8	50.5	43.4	42.2	40.0	40.1	70.2	70.2	76.5	80.0
7	200	90	64.9	64.7	61.1	57.4	52.7	48.9	47.9	49.1	83.4	76.4	81.1	85.1
8	400	90	59.2	59.5	59.0	52.7	45.3	42.0	40.8	42.9	74.8	69.5	70.2	73.7

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
78.3	81.1	85.6	76.3	74.7	67.6	68.3	60.2	57.3	54.1	46.3	36.7
72.3	75.8	77.6	68.1	66.7	62.9	61.5	52.1	48.0	42.1	32.1	22.1
77.6	74.0	74.8	67.0	57.9	52.0	48.6	43.9	42.8	42.3	36.5	31.7
65.7	60.3	63.5	52.2	46.4	39.0	35.4	29.4	27.6	25.2	20.2	19.6

Table B -36
As-Measured Acoustic Data
Airchime K-5-LA, Center-Installed, SD60MAC Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	94.6
2	200	0	89.7
3	400	0	84.1
4	100	45	107.9
5	200	45	103.4
6	100	90	105.1
7	200	90	99.8
8	400	90	87.4
9	100	135	102.7
10	200	135	97.9
11	100	180	99.9
12	200	180	95.5
13	100	270	105.2
14	200	270	99.8
1C	130	0	92.3
2C	230	0	89.1
15O	Cab, Windows Open		94.7
15C	Cab, Windows Closed		79.4

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	72.7	73.8	64.6	53.6	54.9	50.8	51.8	50.3	82.7	87.9	84.9	77.7
3	400	0	67.2	68.3	61.1	50.7	49.8	45.9	43.9	41.0	72.6	81.3	77.6	73.6
7	200	90	75.7	81.0	71.3	62.3	62.6	56.5	56.7	56.4	86.9	92.0	91.0	96.5
8	400	90	69.1	74.7	65.7	55.8	55.3	48.2	48.9	49.2	79.3	84.0	79.7	84.0

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
81.2	78.5	76.6	74.3	74.8	73.3	73.2	69.8	66.5	62.3	57.3	51.9
78.8	73.4	71.5	69.9	71.2	70.5	69.6	65.5	61.2	55.1	47.5	38.3
95.3	89.6	87.7	85.5	84.9	79.4	78.1	74.2	71.2	66.0	60.2	54.0
82.0	75.1	72.8	71.3	72.0	66.8	65.2	60.8	56.2	49.3	41.4	31.8

Table B -37
As-Measured Acoustic Data
Airchime P-3, Knuckle-Installed, SD60MAC Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	112.3
2	200	0	94.4
3	400	0	77.4
4	100	45	106.4
5	200	45	88.4
6	100	90	102.2
7	200	90	88.3
8	400	90	71.9
9	100	135	95.2
10	200	135	82.1
11	100	180	74.1
12	200	180	68.0
13	100	270	101.8
14	200	270	94.5
1C	130	0	111.6
2C	230	0	94.6
15O	Cab, Windows Open		91.3
15C	Cab, Windows Closed		76.7

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	63.3	61.4	59.6	50.0	43.8	43.4	46.6	76.6	69.4	76.2	78.2	81.9
3	400	0	60.5	57.7	59.5	49.6	39.8	39.3	40.4	65.7	58.6	64.1	61.9	64.8
7	200	90	66.8	65.1	61.5	58.8	53.5	51.0	48.6	74.9	81.6	81.1	75.0	81.3
8	400	90	60.8	59.4	59.0	52.5	44.3	41.1	39.7	63.8	69.1	65.8	58.9	64.7

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
82.4	84.8	90.6	83.2	80.9	81.1	80.2	76.4	74.2	70.6	66.5	61.4
65.3	67.3	73.1	67.2	64.6	65.1	63.8	59.2	55.6	50.4	43.9	35.3
80.4	79.5	81.8	76.8	73.7	71.1	69.0	65.8	60.5	56.6	51.9	44.8
63.5	61.9	64.6	60.1	56.3	53.5	51.4	47.2	41.1	35.2	28.0	21.3

Table B -38
As-Measured Acoustic Data
Airchime P-3, Cab Roof-Installed, SD60MAC Locomotive
135 psi

Mic #	Offset (ft)	Offset (deg)	LAeq (dB(A))
1	100	0	110.1
2	200	0	106.0
3	400	0	91.7
4	100	45	105.8
5	200	45	102.0
6	100	90	101.0
7	200	90	96.9
8	400	90	84.7
9	100	135	97.1
10	200	135	94.7
11	100	180	87.0
12	200	180	85.4
13	100	270	100.9
14	200	270	95.3
1C	130	0	109.5
2C	230	0	105.6
15O	Cab, Windows Open		94.5
15C	Cab, Windows Closed		89.1

One-Third Octave Band Sound Levels (dB)

Mic #	Offset (ft)	Offset (deg)	50.0 Hz	63.0 Hz	80.0 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz
2	200	0	63.6	61.4	58.6	50.9	45.2	44.8	50.7	78.8	84.4	87.4	89.6	93.1
3	400	0	61.1	57.9	59.0	49.8	40.9	40.7	43.8	67.8	71.8	74.9	76.3	79.5
7	200	90	67.0	65.0	61.0	60.1	54.0	50.9	51.1	80.1	81.3	84.1	80.8	88.7
8	400	90	61.2	59.5	58.7	53.4	44.9	42.4	41.6	71.3	72.9	74.4	70.5	76.9

800 Hz	1000 Hz	1250 Hz	1600 Hz	2000 Hz	2500 Hz	3150 Hz	4000 Hz	5000 Hz	6300 Hz	8000 Hz	10000 Hz
95.1	94.0	102.2	96.7	93.3	92.1	90.6	86.9	84.7	81.0	76.8	72.2
81.7	80.8	87.2	82.1	79.1	79.4	77.9	73.3	69.6	64.5	58.4	50.6
92.4	89.0	89.6	85.4	82.3	78.4	76.5	74.9	69.7	64.3	59.5	51.8
79.1	75.4	78.0	74.1	69.6	66.1	63.4	60.3	53.8	47.1	40.3	29.4

APPENDIX C
DIRECTIVITY CONTOURS

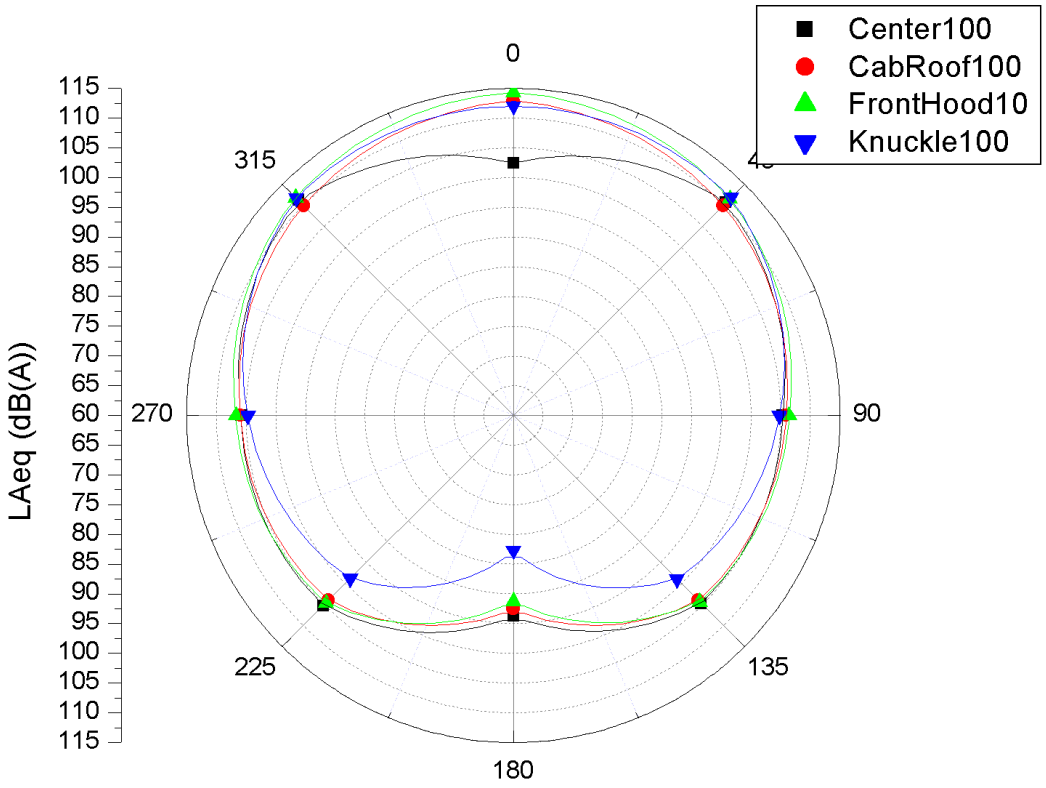

Figure C-1
Acoustic Data Measured 100 ft from horn
Airchime K-5-LA, GP-40 Locomotive
135 psi delivered to horn

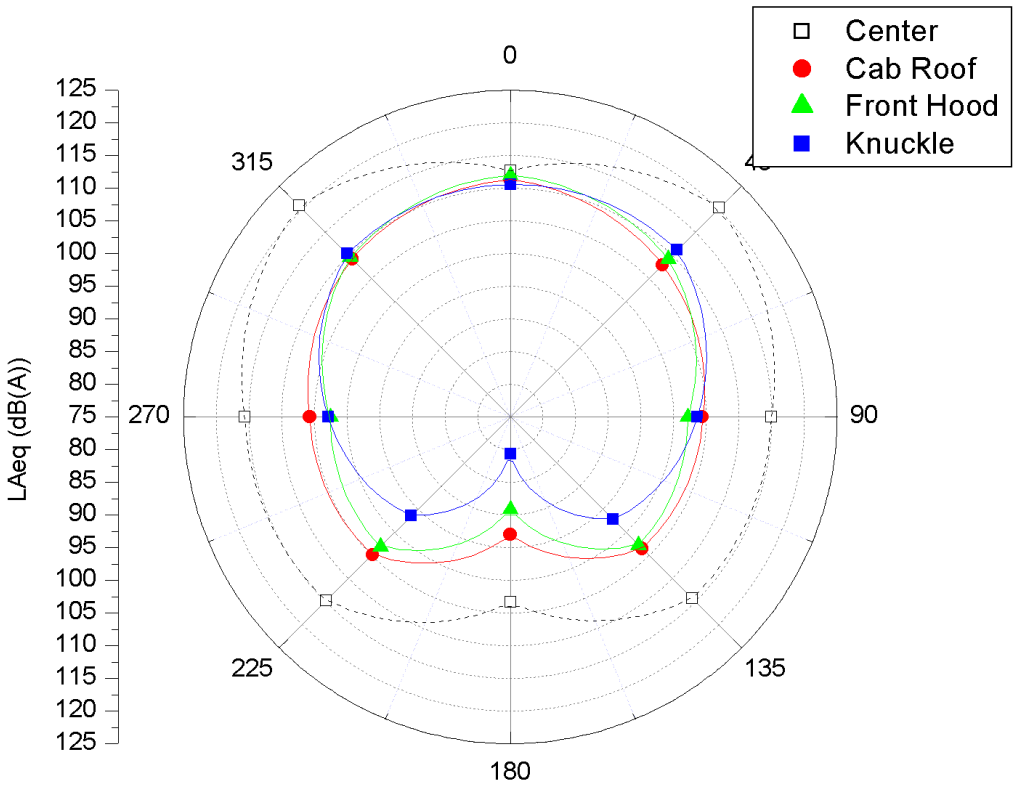

Figure C -2
Acoustic Data Measured 100 ft from horn
Airchime K-5-LA, GP-40 Locomotive
111 dB(A) 100 ft forward of the locomotive

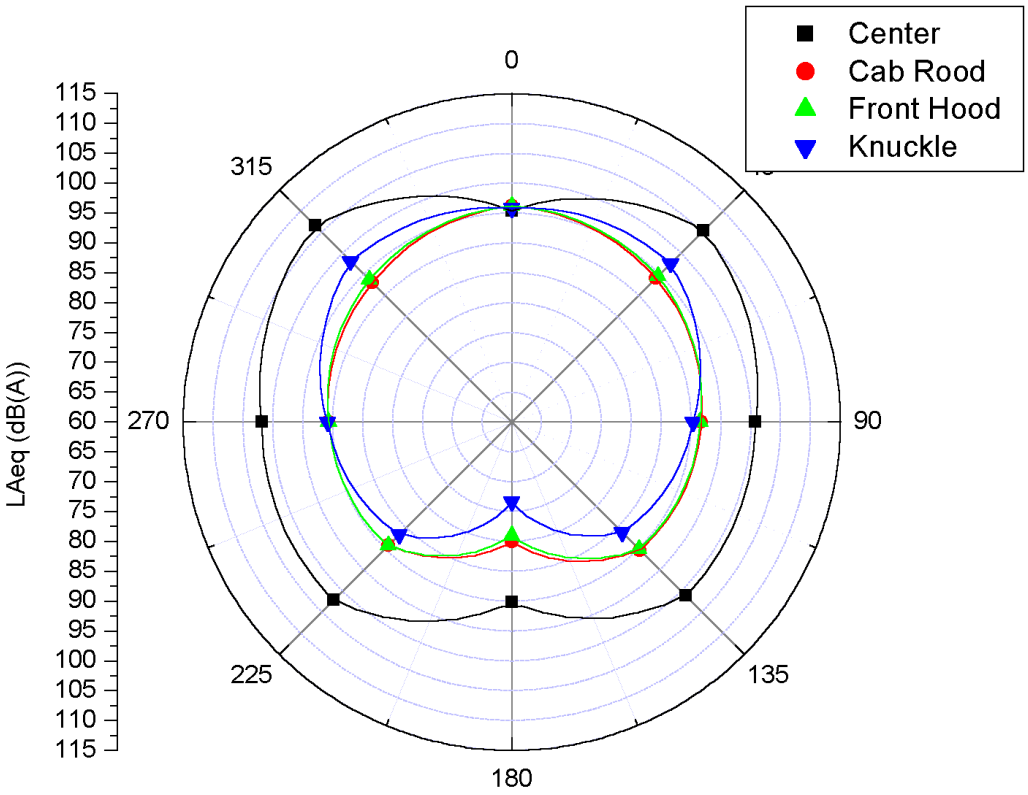

Figure C -3
Acoustic Data Measured 100 ft from horn
Airchime K-5-LA, GP-40 Locomotive
96 dB(A) 100 ft forward of the locomotive

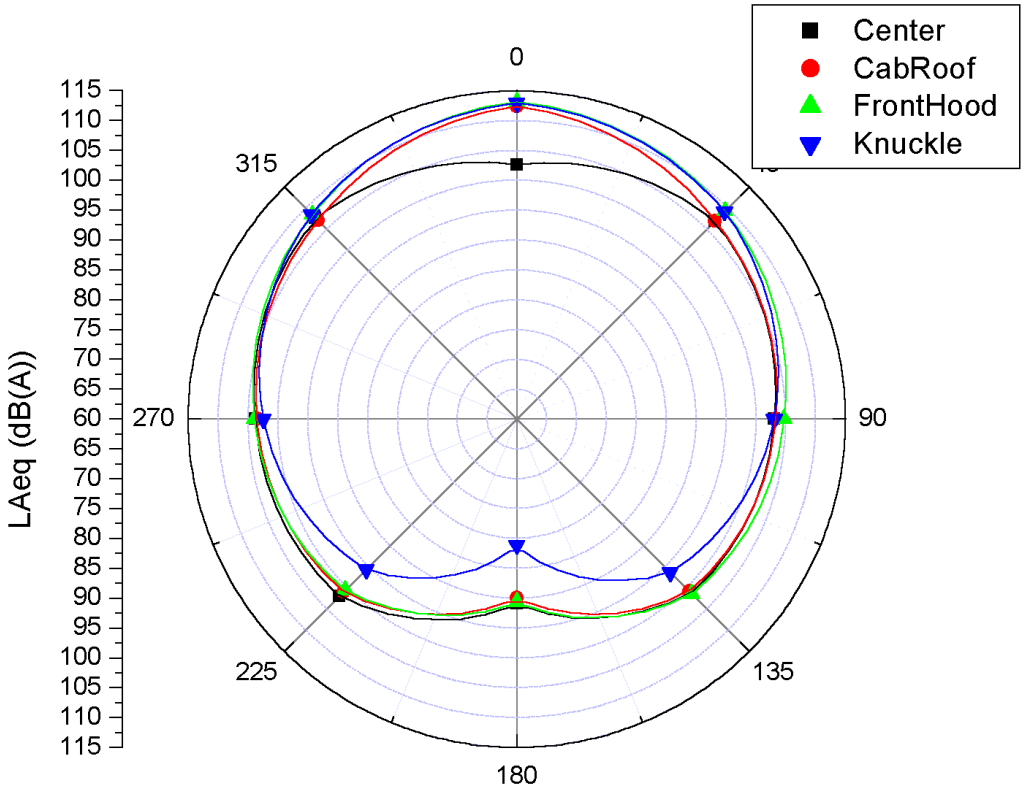

Figure C -4
Acoustic Data Measured 100 ft from horn
Leslie RS-3L, GP-40 Locomotive
135 psi delivered to horn

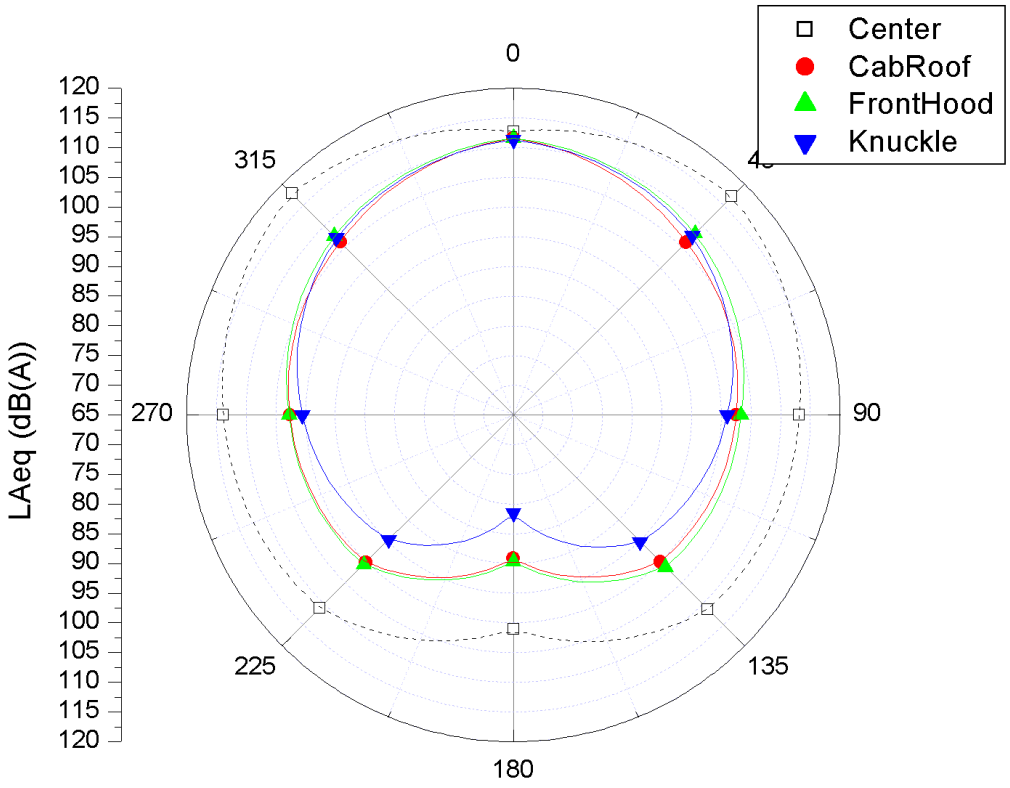

Figure C -5
Acoustic Data Measured 100 ft from horn
Leslie RS-3L, GP-40 Locomotive
111 dB(A) 100 ft forward of the locomotive

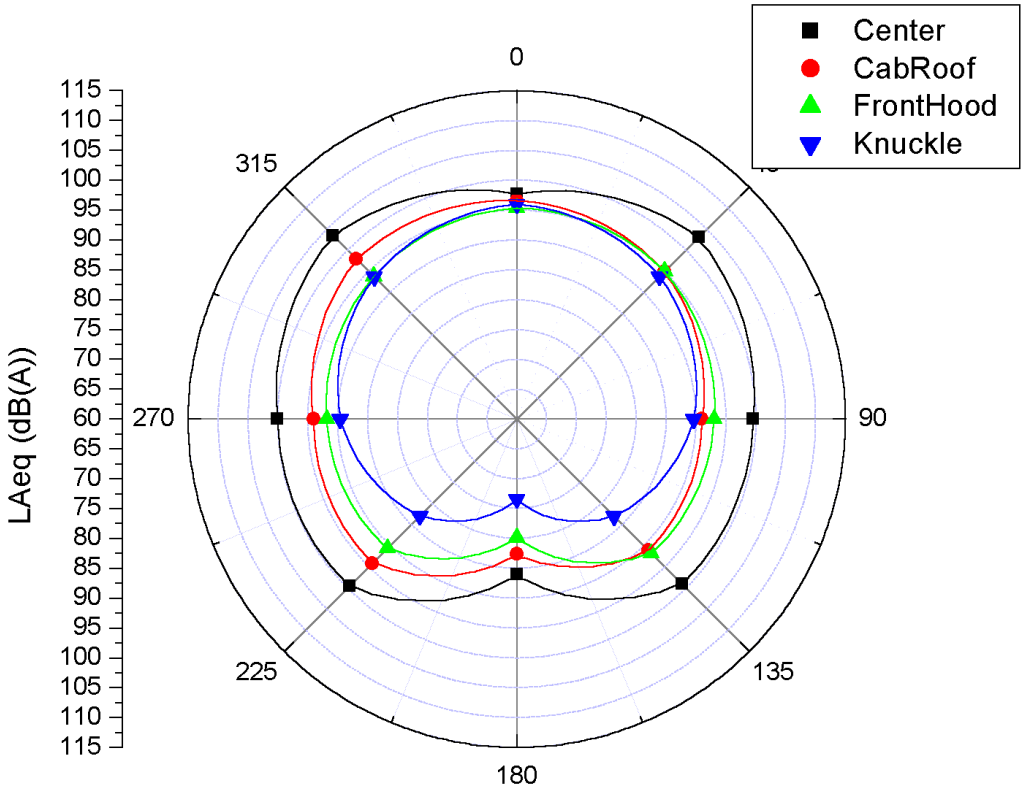

Figure C -6
Acoustic Data Measured 100 ft from horn
Leslie RS-3L, GP-40 Locomotive
96 dB(A) 100 ft forward of the locomotive

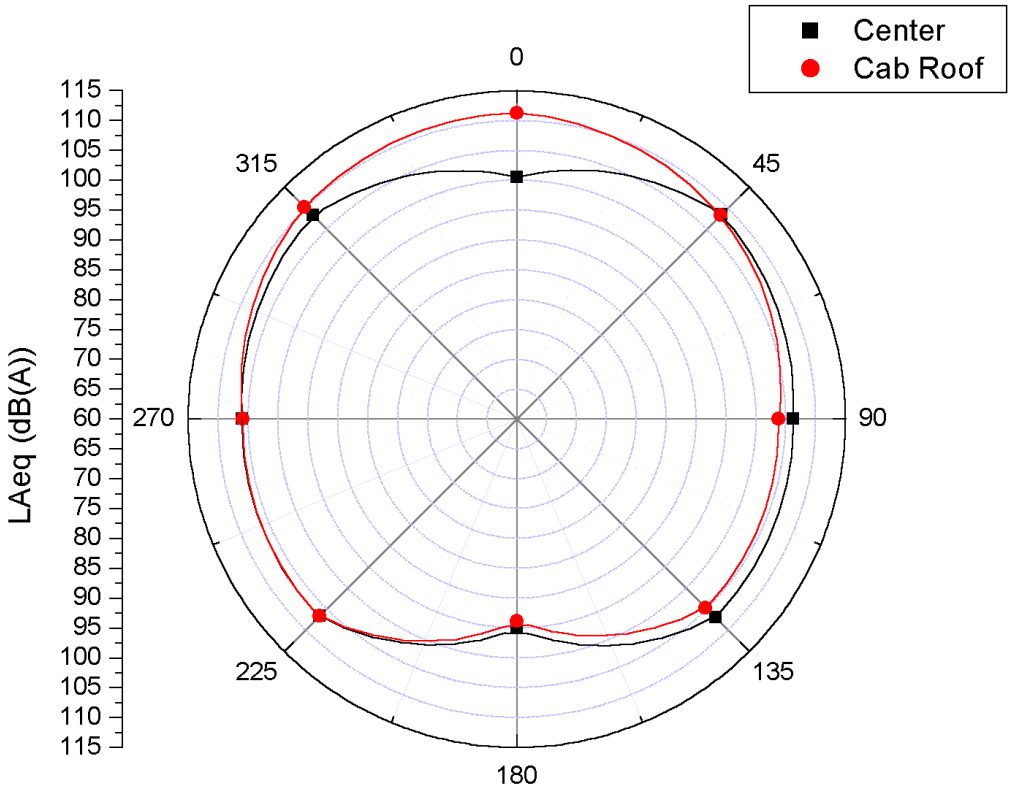

Figure C -7
Acoustic Data Measured 100 ft from horn
Airchime K-5-LAR24, GP-40 Locomotive
135 psi delivered to horn

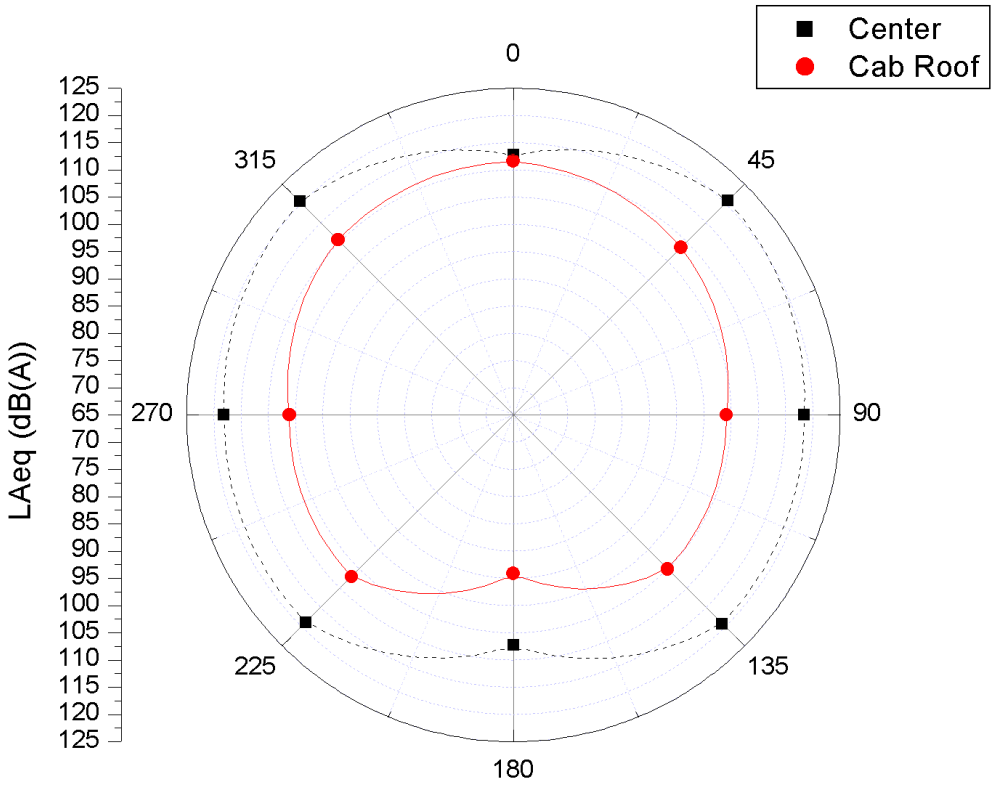

Figure C -8
Acoustic Data Measured 100 ft from horn
Airchime K-5-LAR24, GP-40 Locomotive
111 dB(A) 100 ft forward of the locomotive

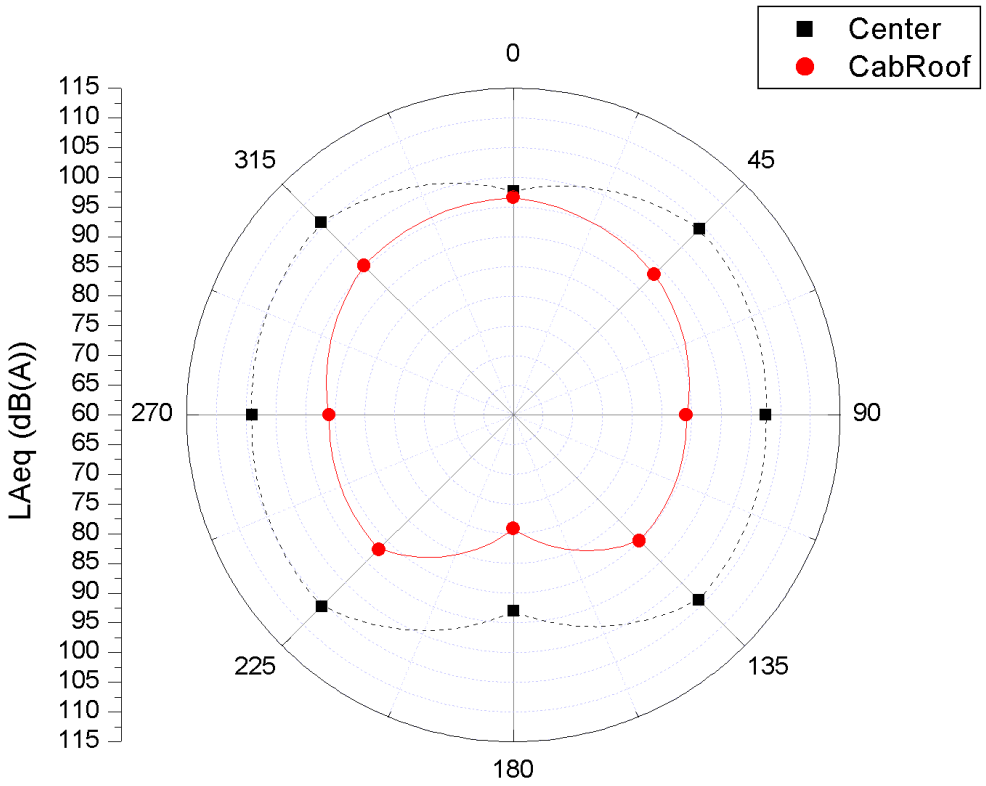

Figure C -9
Acoustic Data Measured 100 ft from horn
Airchime K-5-LAR24, GP-40 Locomotive
96 dB(A) 100 ft forward of the locomotive

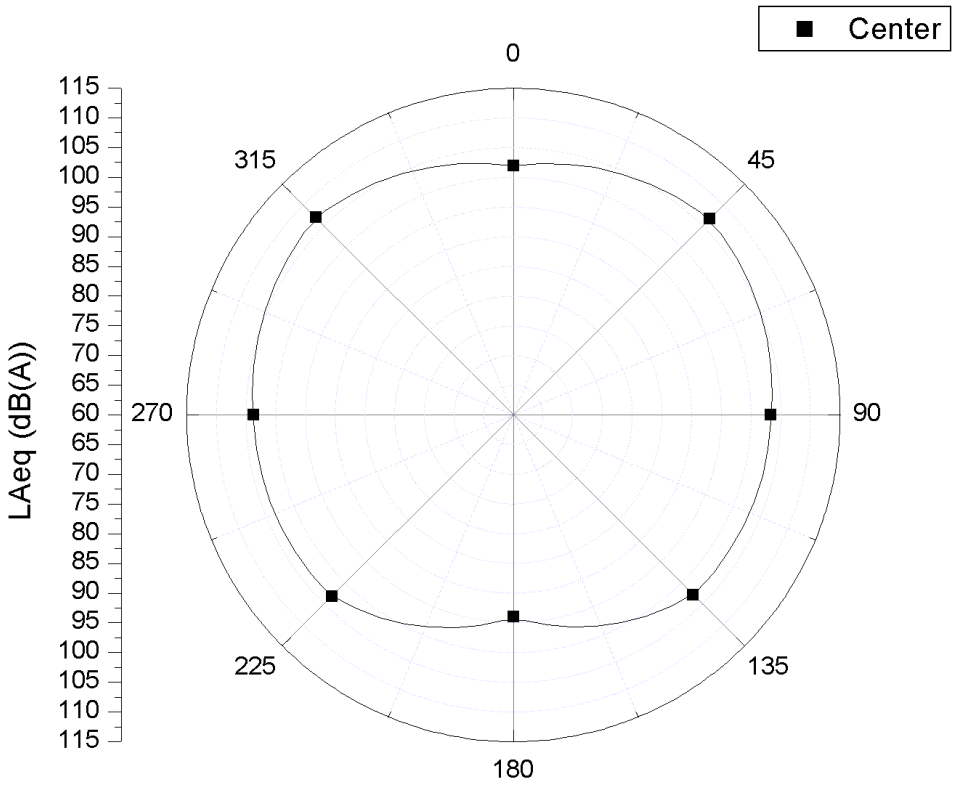

Figure C -10
Acoustic Data Measured 100 ft from horn
Leslie RS-3L-RF, GP-40 Locomotive
135 psi delivered to horn

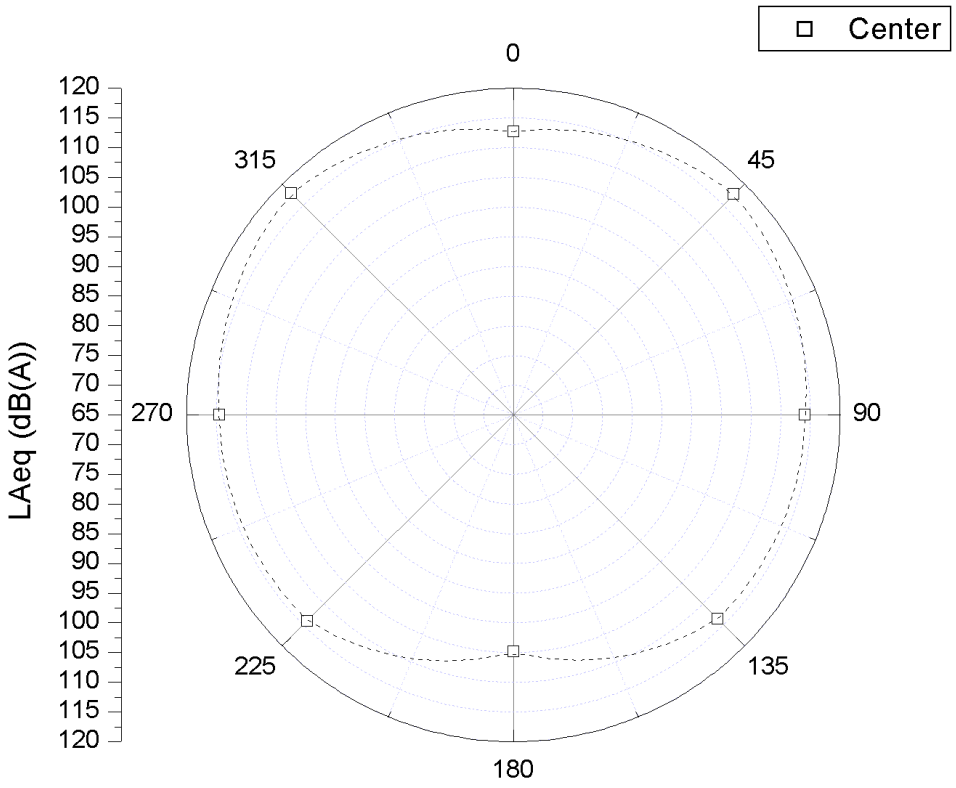

Figure C -11
Acoustic Data Measured 100 ft from horn
Leslie RS-3L-RF, GP-40 Locomotive
111 dB(A) at 100 ft

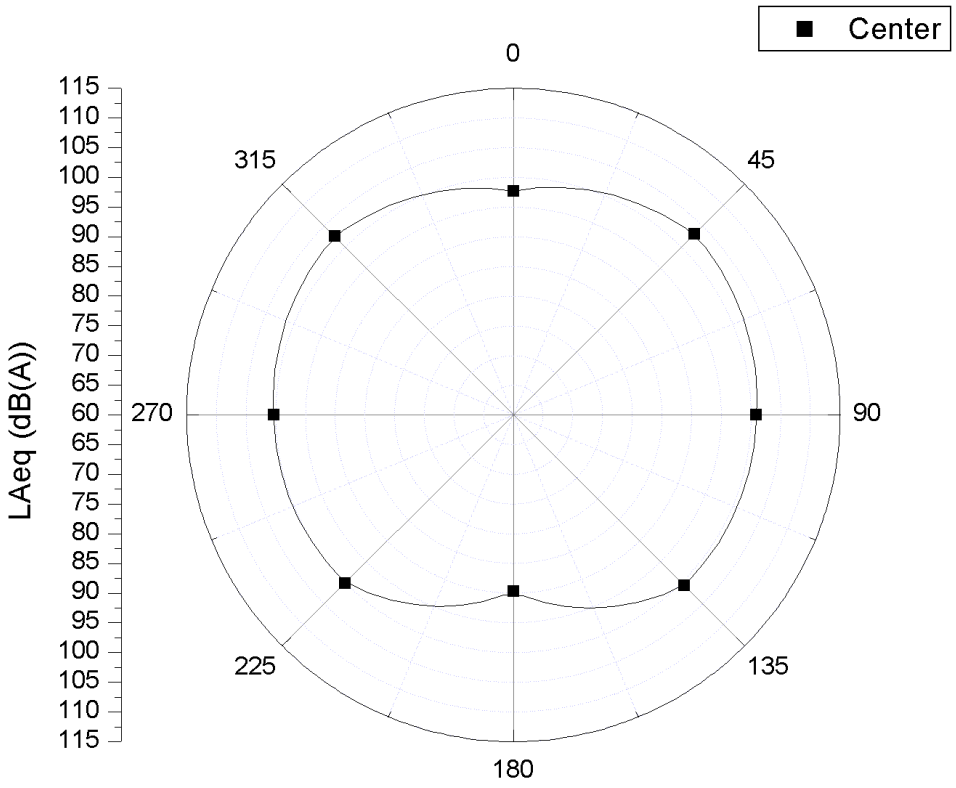

Figure C -12
Acoustic Data Measured 100 ft from horn
Leslie RS-3L-RF, GP-40 Locomotive
96 dB(A) at 100 ft

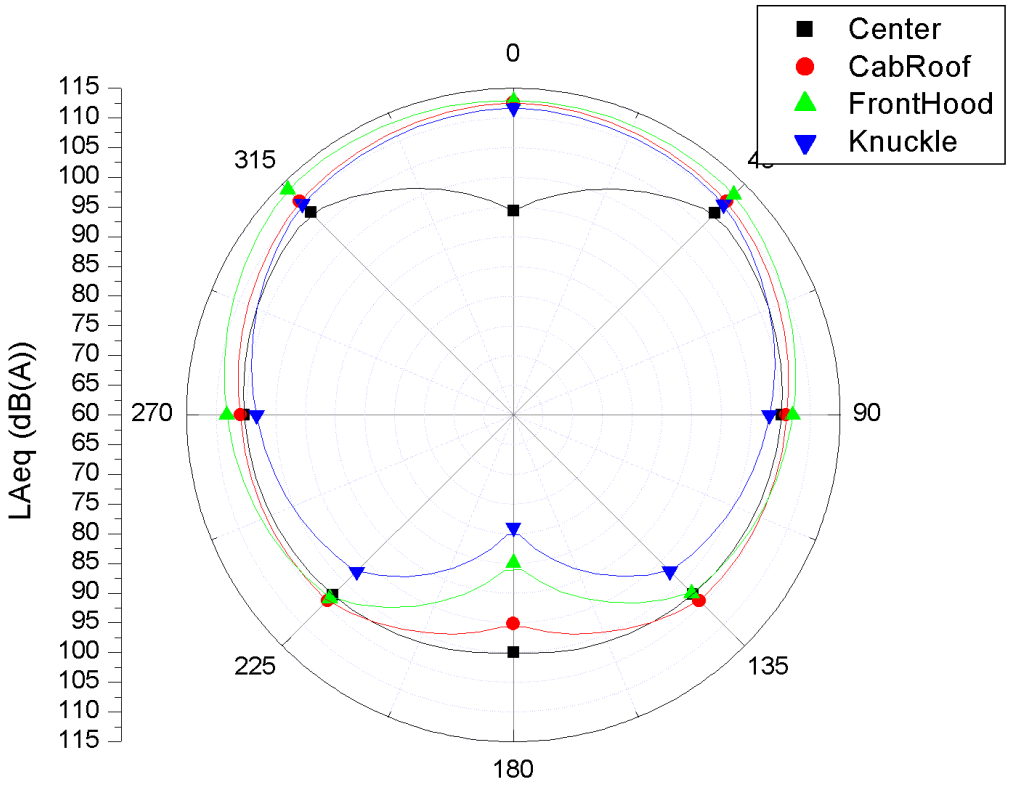

Figure C -13
Acoustic Data Measured 100 ft from horn
Airchime K-5-LA, SD60MAC Locomotive
135 psi delivered to horn

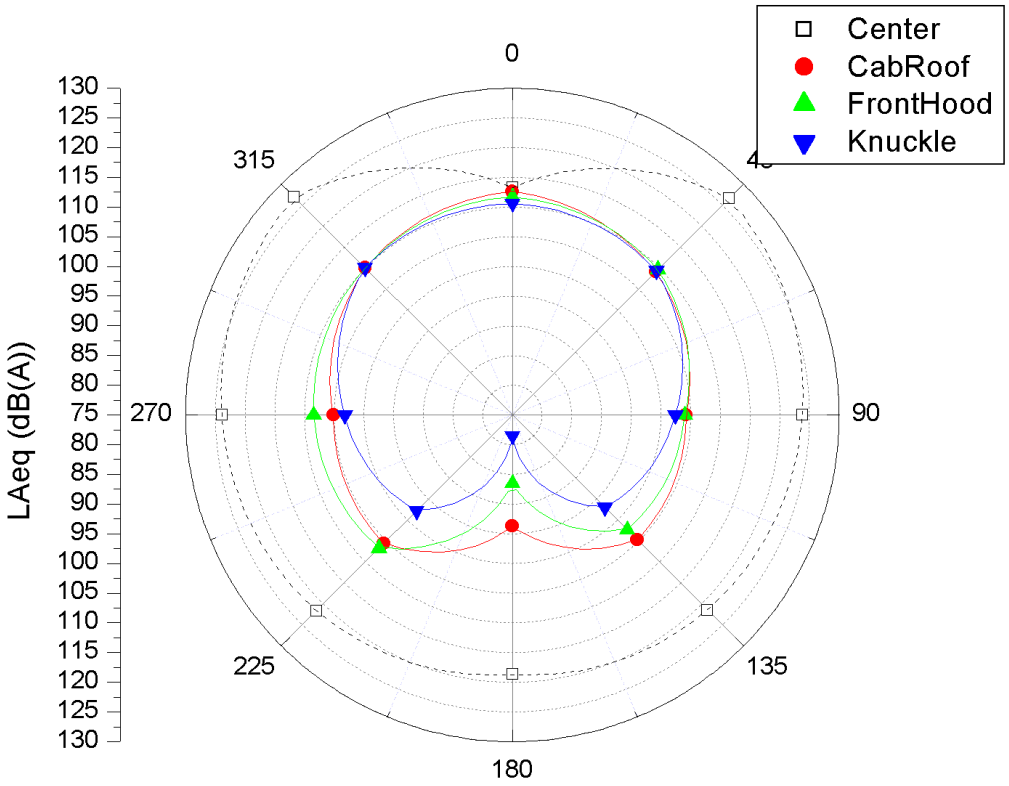

Figure C -14
Acoustic Data Measured 100 ft from horn
Airchime K-5-LA, SD60MAC Locomotive
111 dB(A) at 100 ft

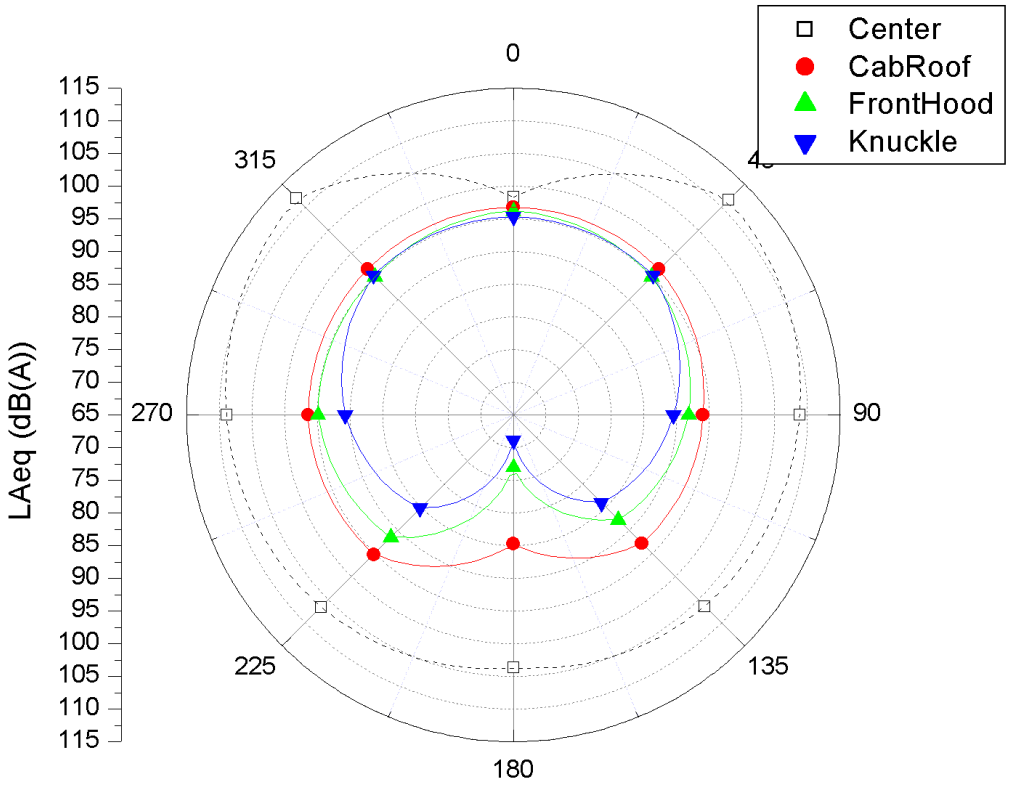

Figure C -15
Acoustic Data Measured 100 ft from horn
Airchime K-5-LA, SD60MAC Locomotive
96 dB(A) at 100 ft

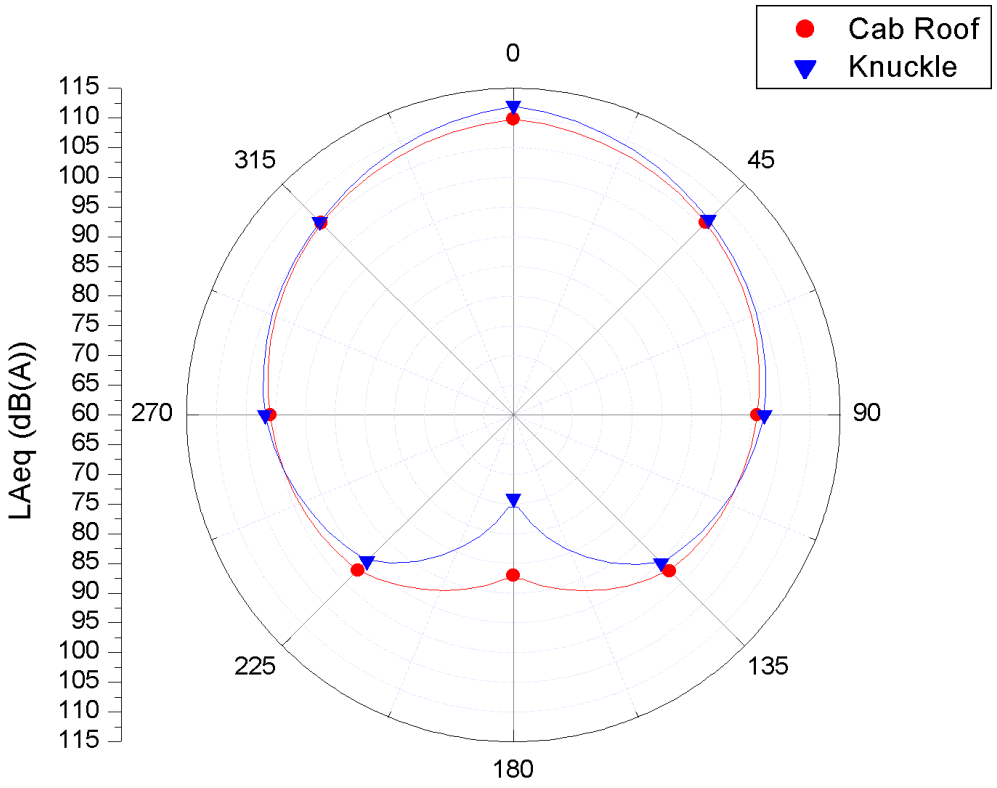

Figure C -16
Acoustic Data Measured 100 ft from horn
Airchime P-3, SD60MAC Locomotive
135 psi delivered to horn

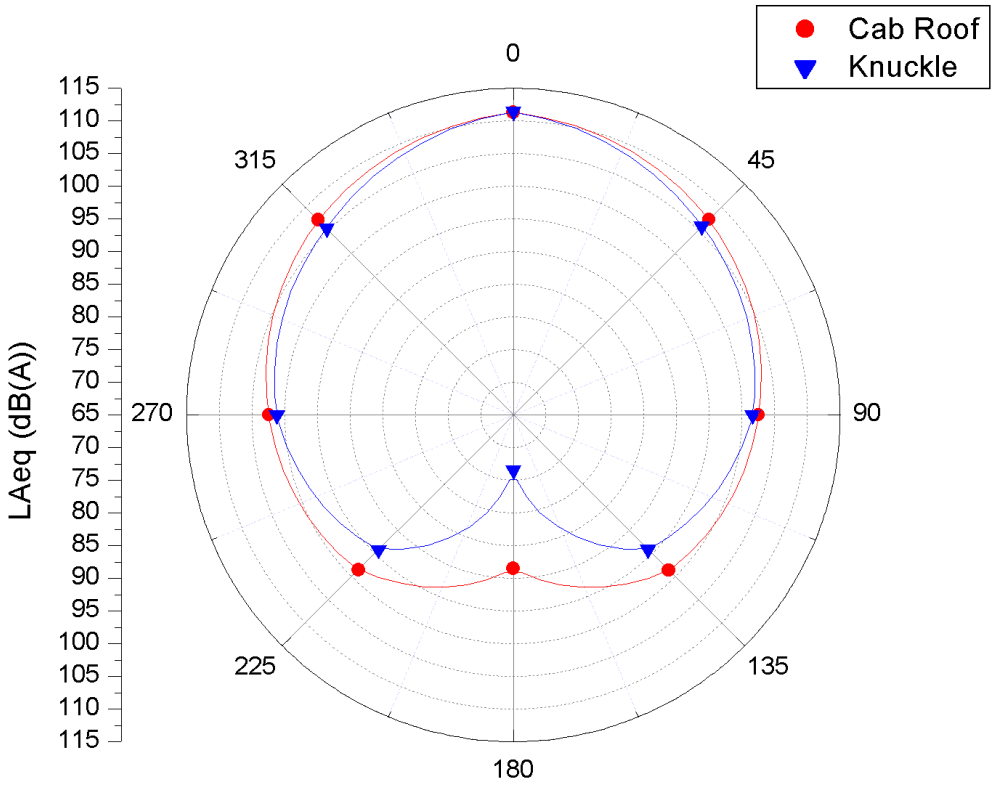

Figure C -17
Acoustic Data Measured 100 ft from horn
Airchime P-3, SD60MAC Locomotive
111 dB(A) at 100 ft

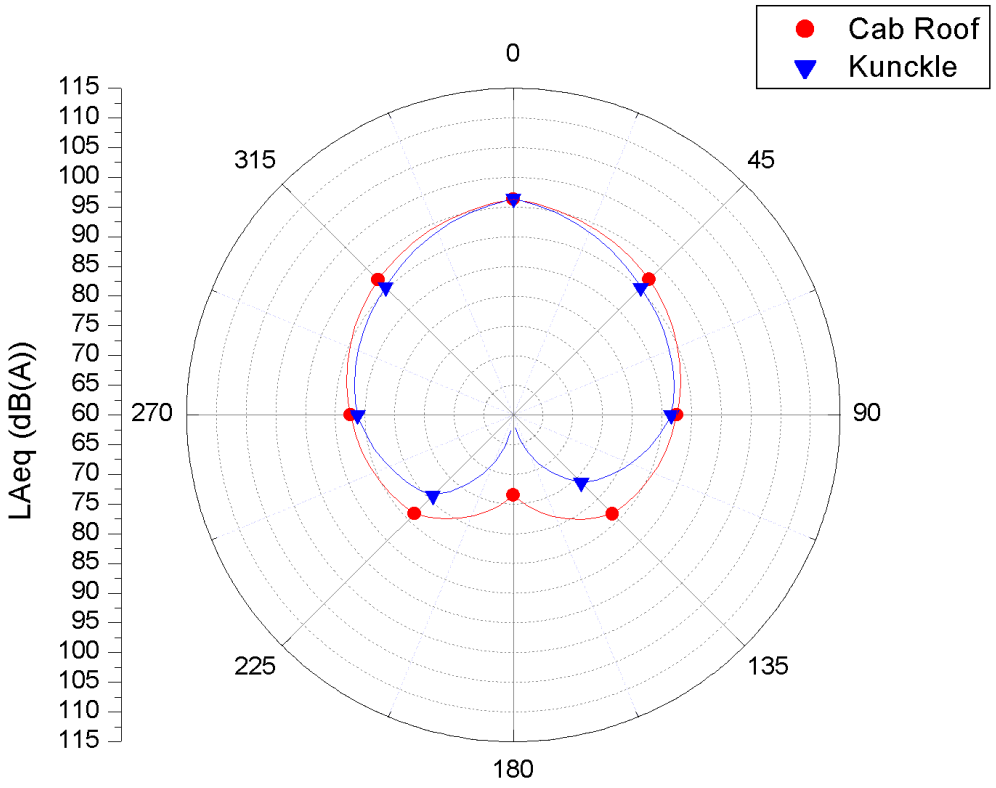

Figure C -18
Acoustic Data Measured 100 ft from horn
Airchime P-3, SD60MAC Locomotive
96 dB(A) at 100 ft